ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS

A THESIS SUBMITTED TO

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT (PUNJAB)

IN THE PARTIAL FULFILLMENT

FOR THE AWARD OF DEGREE OF

MD

IN

RADIODIAGNOSIS

2024

Submitted By

DR. ANANYA SINGH

DEPARTMENT OF RADIODIAGNOSIS
DAYANAND MEDICAL COLLEGE AND HOSPITAL

LUDHIANA, PUNJAB

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled "**ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS"** submitted towards partial fulfillment of the requirements for the award of **MD in RADIODIAGNOSIS** degree to BFUHS is a compilation of original work carried out by me under the supervision of **Dr. Kavita Saggar,** Professor & Head, Department of Radiodiagnosis, **Dr. Harpreet Kaur,** Professor & Head, Department of Pathology and **Dr. Devinderpal Singh Dhanota,** Asst. Professor, Department of Radiodiagnosis. No part of this thesis has formed the basis for the award of any degree previously.

_____

DR. ANANYA SINGH
Department of Radiodiagnosis,
Dayanand Medical College & Hospital,
Ludhiana, Punjab

Date:

Place:

CERTIFICATE OF SUPERVISORS

This is to certify that the work incorporated in this thesis entitled **''ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS''** has been carried out by **Dr. Ananya Singh** under our direct supervision. The data incorporated in this thesis is original and genuine and has been carried out by the candidate herself.

Signature of Supervisor

Dr. Kavita Saggar
Professor & Head
Department of Radiodiagnosis
DMC&H, Ludhiana

Signature of Co-Supervisors

Dr. Harpreet Kaur
Professor & Head
Department of Pathology
DMC&H, Ludhiana

Dr. Devinderpal Singh Dhanota
Assistant Professor
Department of Radiodiagnosis
DMC&H, Ludhiana

Date:

ENDORSEMENT BY THE HEAD OF THE INSTITUTE

This is to certify that the thesis entitled **"ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS"** is a bonafide research work done by **Dr. Ananya Singh** under the supervision of **Dr. Kavita Saggar,** Professor & Head, Department of Radiodiagnosis, **Dr. Harpreet Kaur,** Professor & Head, Department of Pathology and **Dr. Devinderpal Singh Dhanota,** Asst. Professor, Department of Radiodiagnosis.

Principal

Dr. Gurpreet Singh Wander
Principal
DMC&H, Ludhiana

Date:

COPYRIGHT

Declaration by the Candidate

I hereby declare that the Baba Farid University of Health Sciences, Faridkot, shall have the rights to preserve & use this thesis in print or electronic format for academic/study purpose by the research scholar/students.

Signature

Dr. Ananya Singh
Department of Radiodiagnosis,
Dayanand Medical College & Hospital,
Ludhiana, Punjab - 141001

Date:

© Baba Farid University of Health Sciences, Faridkot

This thesis is dedicated to my

parents,

Dr. Bharat Bhushan

&

Mrs. Balwinder Kaur

for their endless love, support,

and encouragement.

ACKNOWLEDGEMENT

No words are enough to express the love and support my parents, ***Dr. Bharat Bhushan*** *and* ***Mrs. Balwinder Kaur*** *have given me throughout my journey. Your sacrifices and belief in me have made this accomplishment possible. Despite suffering from CKD stage-5, my dearest father has always been my pillar of strength.*

I am deeply grateful to my mentor and supervisor, ***Dr. Kavita Saggar****, Professor & Head of Radiodiagnosis, DMC&H, Ludhiana, for her exceptional guidance and support throughout this endeavor. Her expertise, insightful feedback, and continuous encouragement have been invaluable in shaping the direction and outcomes of this study. Her unwavering commitment to my academic growth and professional development has been truly inspiring. I am forever indebted to her for generous allocation of time and resources, and willingness to share her knowledge with me. Her unwavering dedication pushed me to new heights. Her mentorship has not only enriched the quality of my study but also had a profound impact on my personal and intellectual growth. I am truly fortunate to have had the privilege of working under her guidance.*

I wish to express my gratitude to my Co-Supervisors, Dr. Harpreet Kaur, Professor & Head of Pathology Department DMC&H, and Dr. Devinderpal Singh Dhanota, Assistant Professor of Radiodiagnosis, DMC&H for their invaluable contribution, constant help, encouragement, and guidance throughout this venture.

The piece of work would have been incomplete without the help, support, and guidance of my esteemed teachers Dr. Archana Ahluwalia, Dr. Kamini Gupta, Dr. Ritu Dhawan Galhotra, and Dr. Chandan Kakkar who have been valuable guides and teachers.

My sincere thanks to our MR technicians Mr. Durgesh Yadav, Mr. Shibby Matthews, and Mr. Manish Sharma without whom the study would have been nearly impossible. I would like to thank my friends Dr. Angie Garg, Dr. Baljit Kaur, Dr. Saurabh and Dr. Divyanshu as well as my batch mates for their constant support. I would also like to express my gratitude to all my patients and volunteers who participated in the study. I would like to thank Niharika mam for her help in compiling my thesis.

Dr. Ananya Singh

ABBREVIATIONS

ADC	Apparent diffusion coefficient
BBB	Blood-brain barrier
CBF	Cerebral blood flow
CBV	Cerebral blood volume
DLBCL	Diffuse large B-cell lymphoma
DSC	Dynamic susceptibility contrast
DWI	Diffusion-weighted imaging
FLAIR	Fluid attenuated inversion recovery
HGG	High-grade glioma
IDH	Isocitrate dehydrogenase
MRI	Magnetic resonance imaging
MTT	Mean transient time
PWI	Perfusion weighted imaging
ROC	Receiver operating characteristic
ROI	Region of interest
rCBF	Relative cerebral blood flow
rCBV	Relative cerebral blood volume
PSR	Percentage Signal Recovery
rPSR	Relative percentage signal recovery
SWI	Susceptibility weighted imaging
T2WI	T2 Weighted image
T1WI	T1 Weighted image

ABSTRACT

BACKGROUND: Characterization and differentiation of enhancing intracranial malignant tumors such as high-grade glioma, metastasis, and diffuse large B-cell lymphoma can be challenging as there is considerable overlap in their imaging features. Pre-operative differentiation of these tumors is required because their management differs substantially. These tumors vary in hemodynamics in terms of endothelial hyperplasia, vascular density, capillary permeability, loss of BBB integrity, and neoangiogenesis. Perfusion parameters like rCBV, rCBF, Percentage Signal Recovery, and rPSR apart from conventional MR sequences can help differentiate these tumors.

AIM: 1) To evaluate the role of Perfusion Parameters and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.

2) To correlate with histopathological diagnosis wherever possible.

MATERIALS AND METHODS: A prospective study was conducted for one and a half years and included 50 patients who were referred to our institution, Dayanand Medical College and Hospital for MR Brain in the Department of Radio-diagnosis, with clinical suspicion of brain tumor. 11 cases were of DLBCL, 11 cases were of metastasis and 28 cases were of HGG.

RESULTS: Mean rCBV and mean rCBF values were lower in DLBCL (1.67 ± 0.36 and 1.51 ± 0.33) than in HGG (3.59 ± 0.91 and 3.32 ± 0.75) and metastasis (3.28 ± 1.12 and 2.88 ± 0.86). Mean PSR value was high in DLBCL (131.55 ± 19.87), intermediate in HGG (77.25 ± 10.00), and low in metastasis (57.64 ± 5.90). Mean rPSR value in DLBCL was 1.47 ± 0.24, in HGG was 0.89 ± 0.08 and in metastasis was 0.73 ± 0.07. Area under ROC for PSR was 1.000, rPSR was 0.992, rCBV was 0.003 and rCBF was 0.000 in differentiating DLBCL from HGG with a p-value of 0.001. The area under ROC for PSR was 0.961, rPSR was 0.935, rCBV was 0.609 and rCBF was 0.631 in differentiating HGG from metastasis which was statistically significant for PSR and rPSR with a p-value of 0.001. Area under ROC for PSR was 1.000, rPSR was 1.000, rCBV was 0.029 and rCBF was 0.054 in differentiating DLBCL from metastasis with a p-value of 0.001. ANOVA F-test values for PSR (113.323) and rPSR (108.744) were better than rCBV (19.027) and rCBF (25.487) in differentiating the 3 groups with significant p-values.

CONCLUSION: PSR and rPSR can be used in addition to rCBV and rCBF in differentiating intra-axial enhancing brain tumors. Overshoot from the baseline was seen in DLBCL, intermediate PSR was seen in HGG and low PSR was observed in metastasis.

KEYWORDS:Percentage signal recovery (PSR), dynamic susceptibility contrast (DSC), diffuse large B-cell lymphoma (DLBCL), high-grade glioma (HGG), cerebral blood volume (CBV), cerebral blood flow (CBF)

TABLE OF CONTENTS

S. NO.	TOPIC	PAGES
I	INTRODUCTION	1-6
II	AIMS AND OBJECTIVES	7
III	REVIEW OF LITERATURE	8-14
IV	MATERIALS AND METHODS	15-20
V	OBSERVATIONS AND RESULTS	21-38
VI	DISCUSSION	39-48
VII	LIMITATIONS	49
VIII	SUMMARY AND CONCLUSIONS	50-51
IX	BIBLIOGRAPHY	52-57
	APPENDICES – I	
	- PROFORMA	
	- MASTER CHART	
	APPENDICES – II	
	- APPROVAL LETTER OF THESIS PLAN	
	- THESIS PLAN	

LIST OF TABLES

Table No.	Title	Page No.
1.	MRI acquisition parameters	17
2.	Age distribution	21
3.	Gender distribution	22
4.	Clinical presentation	23
5.	Distribution of tumor subtypes	25
6.	Quantitative perfusion values (mean ± S.D.) in diffuse large B-cell lymphoma	26
7.	Quantitative perfusion values (mean ± S.D.) in high-grade glioma	27
8.	Quantitative perfusion values (mean ± S.D.) in metastasis	28
9.	Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from high-grade glioma	29
10.	Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating high-grade glioma from metastasis	31
11.	Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from metastasis	33
12.	F-statistic obtained from one way ANOVA	35
13.	Mean values and standard deviations of perfusion parameters in diffuse large B-cell lymphoma in the previous studies compared with the present study	41
14.	Mean values and standard deviations of perfusion parameters in high-grade glioma in the previous studies compared with the present study	41

15.	Mean values and standard deviations of perfusion parameters in metastasis in the previous studies compared with the present study	42

LIST OF FIGURES

Figure No.	Title	Page No.
1.	Sample signal intensity curve	19
2.	Pie chart showing age group distribution (years) with percentage of cases in the respective age group	21
3.	Pie chart showing the distribution of males and females	22
4.	Clinical presentation	23
5.	Pie chart showing the distribution of tumor subtypes and percentage of cases in each group	25
6.	ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from high-grade glioma	30
7.	ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating high-grade glioma from metastasis	32
8.	ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from metastasis	34
9.	Boxplot depicting variations in rCBV in differentiating the three groups	37
10.	Boxplot depicting variations in rCBF in differentiating the three groups	37
11.	Boxplot depicting variations in PSR in differentiating the three groups	38
12.	Boxplot depicting variations in rPSR in differentiating the three groups	38

LIST OF PICTURES

Picture No.	Title
1.	Case 1: 48-year-old female with histopathologically proven diffuse large B-cell lymphoma. A lobulated lesion showing intermediate signal intensity on FLAIR images is seen involving the body and splenium of corpus callosum, and pericallosal cortex with significant diffusion restriction. The lesion is hyperdense on NCCT. a: DWI, b: ADC, c: FLAIR, and d: NCCT
2.	Case 1: CBF perfusion map shows rCBF value of 1.38 in the lesion.
3.	Case 1: The lesion shows intense homogeneous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
4.	Case 1: Percentage signal recovery of the lesion is 150% and rPSR is 1.7.
5.	Case 2: 55-year-old male with histopathologically proven diffuse large B-cell lymphoma. An ill-defined area showing intermediate signal intensity on FLAIR images is seen involving cortex and subcortical white matter in right frontal lobe with significant diffusion restriction and moderate white matter edema. The lesion is hyperdense on NCCT. a: DWI, b: ADC, c: FLAIR, and d: NCCT
6.	Case 2: CBF perfusion map shows rCBF value of 1.37 in the lesion.
7.	Case 2: The lesion shows nearly homogeneous solid

	post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
8.	Percentage signal recovery of the lesion is 139% and rPSR is 1.5.
9.	Case 3: 67-year-old female with histopathologically proven diffuse large B-cell lymphoma. Two well-defined lesions showing intermediate signal intensity on FLAIR images are seen involving bilateral frontal lobes with diffusion restriction and extensive white matter edema. The lesions are hyperdense on NCCT. a: DWI, b: ADC, c: FLAIR, and d: NCCT.
10.	Case 3: CBF perfusion map shows rCBF value of 1.03 in the lesion.
11.	Case 3: The lesion shows nearly homogeneous solid post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
12.	Case 3: Percentage signal recovery of the lesion is 158% and rPSR is 1.8.
13.	Case 4: 57-year-old female with histopathologically proven high-grade glioma. A lobulated intermediate signal intensity lesion showing areas of cystic degeneration on FLAIR images is seen involving subcortical and deep white matter of right temporoparietal lobe with patchy diffusion restriction. The lesion is heterogeneously hypodense on NCCT. a: DWI, b: ADC, c: FLAIR, and d: NCCT.
14.	Case 4: CBF perfusion map shows rCBF value of 6 in the lesion.
15.	Case 4: Lesion shows heterogeneous post-contrast

	enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
16.	Case 4: Percentage signal recovery of the lesion is 78% and rPSR is 0.81.
17.	Case 5: 62-year-old male with histopathologically proven high-grade glioma. An area of altered signal intensity appearing heterogeneously hyperintense on FLAIR images is seen involving cortex, subcortical, and deep white matter of right temporoparietal lobe with no significant diffusion restriction. The lesion is heterogeneously hypodense on NCCT. a: DWI, b: ADC, c: FLAIR, and d: NCCT
18.	Case 5: CBF perfusion map shows rCBF value of 3.2 in the lesion.
19.	Case 5: Lesion shows thick peripheral post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
20.	Case 5: Percentage signal recovery of the lesion is 80% and rPSR is 0.9.
21.	Case 6: 55-year-old male with histopathologically proven high-grade glioma. A lobulated lesion with intermediate signal intensity is seen on FLAIR images involving the white matter in left parietal lobe with peripheral diffusion restriction on DWI/ADC images. The lesion is heterogeneously hyperdense on NCCT due to hemorrhage. a: DWI, b: ADC, c: FLAIR, and d: NCCT.
22.	Case 6: CBF perfusion map shows rCBF value of 3.7 in the lesion.

23.	Case 6: Lesion shows thick peripheral post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
24.	Case 6: Percentage signal recovery of the lesion is 70% and rPSR is 0.86.
25.	Case 7: 55-year-old female with carcinoma left breast. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in left high frontal lobe showing no diffusion restriction. Extensive perilesional white matter edema is noted. a: DWI, b: ADC, c: FLAIR, and d: T1WI.
26.	Case 7: CBF perfusion map shows rCBF value of 2.8 in the lesion.
27.	Case 7: Lesion shows solid post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
28.	Case 7: Percentage signal recovery of the lesion is 38% and rPSR is 0.7.
29.	Case 8: 51-year-old female with carcinoma right breast. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in right frontal lobe showing no diffusion restriction. Extensive perilesional white matter edema is noted. a: DWI, b: ADC, c: FLAIR, and d: T1WI.
30.	Case 8: CBF perfusion map shows rCBF value of 2.2 in the lesion.
31.	Case 8: Lesion shows vivid heterogenous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI

	(MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
32.	Case 8: Percentage signal recovery of the lesion is 54% and rPSR is 0.71.
33.	Case 9: 74-year-old female with adenocarcinoma pancreas. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in right occipital lobe with patchy diffusion. Mild perilesional white matter edema is noted. a: DWI, b: ADC, c: FLAIR, and d: T1WI.
34.	Case 9: CBF perfusion map shows rCBF value of 2.6 in the lesion.
35.	Case 9: Lesion shows vivid heterogenous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization. a: TIWI b: CBV perfusion map
36.	Percentage signal recovery of the lesion is 60% and rPSR is 0.7.

BABA FARID UNIVERSITY OF HEALTH SCIENCES
Sadiq Road, Faridkot-151203 (Pb.) INDIA
Phone No. 91-1639-256253 and Fax No. 91-1639-256234
Website: www.bfuhs.ac.in, Email: bfuhspc@gmail.com
(BFUHS – UNIVERSITY LIBRARY- Coordinator APC)

11-BFUHS (LI-PC-134)24/924 Dated: July 19, 2024

Plagiarism Verification Certificate (Revised)

Title of the thesis: **Role of Perfusion Parameters And Percentage Signal Recovery Derived from MR Dynamic Susceptibility Contrast Imaging In Enhancing Intra-Axial Brain Tumors**

Total Page: **57 (Fifty-Seven only) eFSPC (eFile Sent for Plagiarism Check)**

Researcher: **Ananya Singh**

Supervisor: **Dr. Kavita Saggar**

Co-Supervisor: **Dr. Harpreet Kaur and Dr. Devinderpal Singh Dhanota**

Research Centre: **Dayanand Medical College & Hospital, Ludhiana**

This is to report that the above thesis was scanned for similarity detection. Process and outcome is given below:

DID:	**2101069**	Software used:	**DRILLBIT**
Date:	**July 19, 2024**	Similarity Index:	**9% (Below 10 Percent)**

Total words count: **10549 (eFSPC)**

The complete report is submitted for review by the Supervisor and Co-Supervisor.

University Coordinator/
Name & Signature (Checked by)
(From University library)

The complete report of the above thesis has been reviewed by the undersigned. (Check Box)

☐ The similarity index is below accepted norms.

☐ The similarity index is above accepted norms, because of the following reasons:

1.....
2.....
3…….....
4…….....
5……

The thesis may be considered for the award of degree. (Relevant documents attached).

Research Scholar **Co-Supervisor** **Co-Supervisor:** **Supervisor**

INTRODUCTION

Intracranial tumors pose a significant health problem. Imaging has an important role in the pre-operative diagnosis and management of these tumors. Magnetic resonance imaging (MRI) is the imaging modality frequently used to evaluate intracranial tumors, and it continues to have an ever-expanding multifaceted role. The role of MRI in the workup of intra-axial tumors can be broadly divided into tumor diagnosis and classification, treatment planning, and post-treatment surveillance.

Conventional MR T1-weighted and T2-weighted sequences are quite sensitive for detecting cerebral tumors. These sequences can identify edema, mass effect, hemorrhage, and tissue necrosis.[1] Conventional MRI sequences are sometimes unable to differentiate between certain contrast-enhancing lesions, thus making the diagnosis challenging.

In addition to conventional MRI techniques, a wide variety of advanced MRI techniques has found their place in clinical practice and is the subjects of intense research. These advanced techniques provide more information than the anatomical information provided by conventional MRI sequences.

Differentiation of the common intra-axial enhancing brain tumors like diffuse large B-cell lymphoma (DLBCL), high-grade glioma (HGG), and metastasis may be challenging on standard MR sequences as they share some similarities in their appearances.

Preoperative differentiation and characterization of these tumors are important, as management and prognosis can alter substantially based on the nature of the tumor. Conventional MRI, therefore cannot always differentiate between these malignant brain tumors.[2] These tumors differ in hemodynamics in terms of endothelial hyperplasia, vascular density, capillary permeability, loss of blood-brain barrier (BBB) integrity, and neoangiogenesis.[3,4]

Definitive diagnosis of cerebral tumors mostly relies on the histopathological analysis of surgically obtained specimens, which requires an invasive procedure, having both surgical risk and risk related to anaesthesia. Histopathology is also not always definitive. Inconclusive results can occur due to heterogeneous histology, diffuse tumor infiltration, and difficulty in accessing the anatomical site which can result in inadequate or unrepresentative samples. A non-invasive imaging-based method of accurate diagnosis would therefore be advantageous.

Perfusion MRI techniques such as dynamic susceptibility-weighted contrast-enhanced (DSC) imaging are considered useful for pathologies that disrupt tissue perfusion. DSC MRI has been used in the diagnosis and grading of cerebral tumors, distinguishing tumor recurrence from radiation necrosis, as well as in evaluating the response to therapy. It has been used to assess the status of capillaries and microvessel attenuation of tumors and is one of the most frequently used techniques for MRI perfusion. It relies on the susceptibility induced signal loss on T2*-weighted sequences, which results from a bolus of gadolinium-based contrast passing through the capillary bed.[5,6]

The commonly calculated perfusion parameters are rCBV, rCBF, and MTT. Changes in rCBV and rCBF maps, reflect the microvessel attenuation and are markers of neoangiogenesis, which is taking place within the lesion.

CBV is defined as the volume of blood in a given amount of brain tissue, most commonly milliliters of blood per 100 g of brain tissue.[6]

CBF is defined as the volume of blood passing through a given amount of brain tissue per unit of time, most commonly milliliters of blood per minute per 100 g of brain tissue.[6]

In most instances, CBV and CBF are difficult to measure in absolute terms, so relative CBV (rCBV) and relative CBF (rCBF) are calculated instead.

rCBV and rCBF are important hemodynamic variables that are used in the characterization of tumors. These parameters are also used in the grading of gliomas. These are unitless, semi-quantitative measures of microvascular density, and provide an estimation of the degree of tumor neoangiogenesis relative to normal brain tissue.[7] rCBV and rCBF values are higher in HGG and metastasis and lower in DLBCL, which can be attributed to the lack of neoangiogenesis in DLBCL.[8]

Both HGG and metastasis have high rCBV and rCBF values with a considerable amount of overlap thus percentage signal recovery (PSR) can be used as an additional parameter along with rCBV and rCBF for differentiating these tumors.[9]

PSR is a novel perfusion parameter obtained from T2*DSC MR imaging. A perfusion curve is obtained that represents the percentage of the signal intensity that is recovered from the baseline at the end of the first pass of contrast material (The baseline being the signal intensity before contrast administration). On administration of intravenous contrast, initially there will be a drop in signal intensity that returns toward the baseline after the first pass. The extent of this recovery is determined by many factors like the rate of blood flow, volume of extravascular space, and contrast leak. PSR provides information on neovascularity and capillary permeability.[9]

There are reports of significantly reduced PSR in metastatic lesions as compared with HGG.[9] HGG has been reported to have a lower recovery of signal intensity than DLBCL. The recovery curve in DLBCL can go above the baseline (overshooting).[10,11]

IMAGING FEATURES OF HIGH-GRADE GLIOMAS

Glioblastoma is the most common and most malignant of all astrocytomas and thus is the most frequent primary malignant brain tumor in adults.[12] Peak incidence is in the 6th decade for glioblastoma isocitrate dehydrogenase (IDH) wild type and is in the 4th–5th decade for glioblastoma IDH mutant type.[13] Despite various therapeutic trials and various advances in the management of these tumors, median survival is quite poor. These are infiltrative and heterogeneous parenchymal tumors that arise and spread from the white matter. Corpus callosum involvement is common. These tumors are poorly circumscribed and display contrast enhancement as a sign of BBB disruption. The core of the tumor appears hypointense on T1WI due to necrosis. The tumor is usually surrounded by edema, which appears hyperintense on T2WI and fluid-attenuated inversion recovery (FLAIR) images. These tumors have thick, irregularly enhancing margins and a central necrotic core, which may have a hemorrhagic component.

Multifocal disease is found in approximately 20% of cases, where multiple areas of enhancement are connected by an abnormal white matter signal which is representing the microscopic spread of tumor cells. Multicentric disease, on the other hand is where no such connection can be seen.

The diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) can provide valuable information concerning the suspected degree of malignancy of astrocytic tumors. More recent multimodal MRI techniques, such as diffusion and perfusion sequences have provided supplementary information about the characteristics of the tumor itself and enabled a more accurate diagnosis. Perfusion-weighted imaging (PWI) reveals an increase in the cerebral blood flow corresponding to neoangiogenesis. MR spectroscopy shows elevated choline, decreased N-acetylaspartate (NAA), and a lipid/lactate peak.

IMAGING FEATURES OF DIFFUSE LARGE B-CELL LYMPHOMA

CNS lymphoma is the second most frequent primary brain malignancy in adults after gliomas, accounting for approximately 7% of all malignant tumors.[14] Diffuse large B-cell lymphoma (DLBCL) of the CNS corresponds to 80%–85% of all CNS lymphomas and occurs almost always in immunocompetent patients. DLBCL is EBV-negative and has an unknown etiology.[15]

DLBCL usually appears as single or multiple (30%–35%) parenchymal masses, with supratentorial location (>80%). DLBCL has a predilection for basal ganglia, periventricular regions, midline, and corpus callosum and is frequent in cerebral hemispheres. Rarely these tumors are found in the posterior fossa and spinal cord. Associated leptomeningeal or subependymal enhancement can be present. Parenchymal lesions are mostly solid and homogeneous but can be well-defined expansive to ill-defined infiltrative lesions.[15-19] DLBCL is frequently hyperattenuating on NCCT, which is generally the first-line radiologic examination, and suspicion at this point may lead to corticosteroid avoidance. DLBCL typically appears hypointense on T2WI with marked diffusion restriction on DWI. Nevertheless, a T2-blackout effect consisting of persistent hypointensity on b 1000 images due to a very low T2 signal may lead to misinterpretation. Thus, ADC map hypointensity might be more reliable than b 1000 hyperintensity in the assessment of actual diffusion restriction.[15-19] Recent literature reports the presence of hemorrhage on imaging in up to 50% of patients evaluated with SWI and heterogeneous or ring enhancement, which is usually associated with necrosis in up to 10%–15% of cases.[20,21] MR spectroscopy demonstrates elevated choline and lipids.

IMAGING FEATURES OF INTRACRANIAL METASTASIS

Intracranial metastasis usually appears iso- to hypointense to gray matter on T1WI and is of variable signal intensity on T2WI.[22] Vasogenic edema typically involves white matter and is most often disproportionate to the size of the lesion but can be absent in some cases.[22] Other imaging features are a spherical, delineated shape and ring enhancement of larger lesions after contrast administration, likely secondary to central necrosis. These lesions can be hemorrhagic with hemorrhage showing varying signal intensities on T1WI and T2WI, depending on different stages over time.[22] There is hematogenous spread of metastasis, so they usually occur at the gray-white matter junction or watershed zones.[23] MR spectroscopy shows elevated choline and a prominent lipid signal with decreased or absent creatine.

AIMS AND OBJECTIVES

1. To evaluate the role of Perfusion Parameters and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.
2. To correlate with histopathological diagnosis wherever possible.

REVIEW OF LITERATURE

Aronen et al (1994) evaluated the utility of MR CBV maps. A total of 19 patients were included in the study. These patients were histopathologically proven as the cases of gliomas. In the high-grade glioma group, the maximum CBV values were 0.82 to 5.40. In the low-grade glioma group, the maximum CBV values were 1.01 to 1.21. The difference among both groups was statistically significant. Maximum CBV was associated with mitotic activity and vascularity of the tumor and not with cellular atypia, endothelial proliferation, necrosis, or cellularity. In conclusion, CBV maps provide the diagnostic information that is not available with conventional MRI sequences and offer a functional parameter for assessing glioma grade and regions of focal activity.[24]

Hartmann et al (2003) assessed the usefulness of perfusion-weighted echo-planar MRI for differentiation between primary supratentorial lymphomas (PCNSL) and glioblastoma multiforme (GBM). A total of 24 patients, 12 with PCNSL and 12 with GBM were evaluated. This study used a 1.5 T MR imager. Using DSC MR Imaging, the intensity-time curves of each tumor were analyzed. Relative regional cerebral blood volume ratios (rrCBV [tumor/contralateral white matter (WM)]) were calculated to find out whether these parameters can be useful in differentiating PCNSL from GBM. The maximum rrCBV ratio in the PCNSL was lower in comparison to that of the GBM. Comparing the intensity-time curves for the two groups, PCNSL showed a characteristic curve. There was a significant increase in signal intensity above the baseline, which was likely secondary to the massive leakage of contrast media into the interstitial space. PCNSL had low maximum CBV ratios and had a typical intensity-time curve. These two parameters can be useful in distinguishing PCNSL from GBM.[10]

Liao et al (2008) evaluated nine patients who were histopathologically proven as the cases of PCNSLs and another eleven patients who were histopathologically proven as the cases of HGG. A 1.5 T MRI scanner

was used for this study and DSC perfusion MRI was performed. The maximum rCBV, signal intensity-time curves, and PSR values were obtained. Perfusion was low in PCNSLs as compared to HGG. PSR was significantly higher in PCNSLs as compared to HGG. This difference in perfusion characteristics between PCNSLs and HGG was likely secondary to different vascularity and different patterns of contrast agent leakage. These parameters might be helpful in the diagnosis and pre-operative differentiation between these tumors, as they can sometimes have similar appearances on conventional MRI sequences.[11]

Rizzo et al (2009) undertook a study to correlate ADC values and relative regional cerebral blood volume (rrCBV) to the histopathological findings in patients with primary and secondary brain tumors. For evaluating the role of PWI and DWI in the characterization of cerebral tumors, a total of 98 patients with cerebral tumors were evaluated. 46 of these were primary tumors (9 were low-grade gliomas, 2 were gliomatosis cerebri, 9 were lymphomas, and 19 were high-grade gliomas), and 52 of these were secondary tumors. Conventional MR imaging along with DWI and dynamic contrast susceptibility PWI was performed. ADC and rrCBV values were calculated and it was concluded that DWI has a role in the differential diagnosis of cystic cerebral masses but not in tumor characterization. PWI may help differentiate high-grade gliomas from low-grade gliomas and lymphomas from high-grade gliomas.[25]

Jarnum et al (2009) did a prospective study including a total of 28 patients with contrast-enhancing brain tumors. The study was performed on a 3T MR scanner using DSC-MRI and PC ASL. Normalized tumor blood flow (nTBF) values were evaluated on ASL CBF (ASL nTBF) and DSC rCBF maps (DSC nTBF). Absolute perfusion values were measured with PC ASL. For normalization, ROIs were placed in tumor tissue, cerebellum, and in contralateral normal-appearing GM and WM. It was concluded that PC ASL can be used as

an alternative to DSC-MRI for the evaluation of perfusion in brain tumors. This method has fewer susceptibility artifacts as compared to that of DSC-MRI. This method can be used in patients with renal failure because no contrast material is injected.[26]

Ho Lee et al (2010) did a retrospective study and evaluated the clinical records and MRI findings in 13 patients. These patients were histopathologically proven as cases of primary CNS lymphoma. The evaluation was done between January 2006 to November 2008. The relative cerebral blood volume ratios (rCBV) of these tumors were calculated. These tumors showed relatively low values of maximum rCBV ratio in most patients, regardless of whether it was a primary or secondary CNS lymphoma. Thus, it was concluded that PWI could be helpful in the diagnosis of CNS lymphoma.[27]

Mangla et al (2011) conducted a retrospective study that included 66 patients. These patients were proven as cases of primary CNS lymphoma, GBM, and metastasis on histopathology. 22 patients were present in each group. rCBV, mean PSR, min PSR, and max PSR values were calculated. For normalization contralateral white matter was used. It was concluded that the mean PSR was high in lymphoma, intermediate in GBM, and low in metastasis. F-values obtained from 1-way ANOVA analysis for mean, min, and max PSR ratios were better than those of rCBV in differentiating between the 3 groups. PSR can be used as an additional parameter that can help in differentiating the common intracerebral malignant lesions.[3]

C.H. Toh et al (2013) conducted a study evaluating CBV, corrected CBV, and leakage coefficient in the enhancing portion of intracranial tumors. 15 cases of PCNSLs and 20 cases of glioblastomas were evaluated. CBV and corrected CBV values were calculated by dividing the tumor values by those obtained from contralateral NAWM. A paired t-test was used for comparing tumor K2 and NAWM K2, as well as tumor CBV ratios with and without leakage correction. A comparison of CBV, corrected CBV, and K2 values amongst PCNSLs and

glioblastomas was done. It was found that the corrected CBV ratios were higher than the uncorrected ones for both tumors. PCNSLs had higher K2 value and lower CBV and corrected CBV ratios when compared with glioblastomas. Thus, PCNSL can be differentiated from glioblastoma with the help of CBV ratios, corrected CBV ratios, and K2.[28]

Xing et al (2014) evaluated a total of 12 patients with PCNSL and 26 patients with HGG. The values of rCBV and PSR were obtained. Receiver operating characteristic (ROC) analysis was performed to determine the optimum thresholds for differentiating these tumors. Sensitivity, specificity, PPV, NPV, and accuracy for identifying the tumor types were calculated. The optimum threshold of 2.56 for rCBV provided sensitivity, specificity, PPV, NPV, and accuracy of 96.2, 90, 92.6, 94.7, and 93.5 %, respectively for determining PCNSL. A threshold value of 0.89 for PSR optimized differentiation of PCNSL and HGG with a sensitivity, specificity, PPV, NPV, and accuracy of 100, 88.5, 87, 100, and 93.5 %, respectively. Combining rCBV with PSR seemed to improve the differentiation of PCNSL and HGG with a specificity of 98.5 % and an accuracy of 95.7 %.[29]

Smitha et al (2015) conducted a prospective study and evaluated the potential of rPSR values, in addition to rCBV and rCBF for differentiating high- and low-grade gliomas. This study included 39 patients who had low-grade glioma and 25 patients who had high-grade glioma. rPSR, rCBV, and rCBF values were calculated. There were statistically significant variations in rPSR, rCBV, and rCBF values between low- and high-grade gliomas. ROC curve analysis for each yielded 96% sensitivity and 71.8% specificity; 88% sensitivity and 69.2% specificity; and 72% sensitivity and 66.7% specificity respectively. AUC from ROC curve analysis yielded 0.893, 0.852, and 0.702 for rPSR, rCBV, and rCBF, respectively. rPSR calculation with the validation software yielded 92.3% sensitivity and 72% specificity with an AUC of 0.864. It was concluded that rPSR values correlate

inversely, while rCBV and rCBF values correlate directly with the tumor grade. The diagnostic performance of rPSR in this study was found to be better than rCBV and rCBF values. [4]

Goyal et al (2017) did a retrospective review of pre-treatment MRI, including DSC-MR perfusion images in a total of 15 patients diagnosed with CNS lymphoma. As a control group, DSC-MR perfusion MR of histopathologically proven cases of 18 GBMs (group 2), 13 metastasis (group 3), and 10 anaplastic-enhancing gliomas (group 4) patients were also reviewed. ROIs were placed at the most enhancing area of the tumor on T1WI contrast-enhanced axial images. CBV maps were obtained in all four groups. For normalization contralateral white matter was used. Mean and maximum rCBV values were obtained in all four groups. The enhancing component of CNS lymphomas showed lower mean rCBV values in comparison to the enhancing component of GBM, metastasis, and anaplastic-enhancing gliomas. Maximum rCBV values of the enhancing component of CNS lymphoma were significantly lower than GBM and metastasis and were not significantly lower than anaplastic-enhancing gliomas. Thus, low mean rCBV in an enhancing portion of the tumor strongly favors the diagnosis of CNS lymphoma. This can help in the differentiation of CNS lymphoma from other enhancing malignant lesions.[30]

Soni et al (2017) evaluated 30 patients diagnosed with brain tumors (16 meningiomas, 6 gliomas, 3 metastasis, 2 cerebellopontine angle schwannoma, 1 central neurocytoma, and 2 low-grade gliomas) using a 3T MR scanner. Values of CBF, regional cerebral blood flow (rCBF), and regional cerebral blood volume (rCBV) were evaluated in tumor (T), in contralateral normal gray matter (GM), and white matter (WM). Tumor-to-GM or WM CBF, rCBF, and rCBV ratios were calculated for estimation of normalized perfusion values (i.e., ASL normalized tumor blood flow [nTBF], DSC normalized tumor blood flow [nTBF], and DSC normalized tumor blood volume [nTBV]) from ASL and DSC techniques. ASL and DSC MRI-derived perfusion parameters were

then compared. Mean values for ASL nTBF and DSC nTBF using contralateral GM as the reference point were 2.98 ± 1.67 and 2.91 ± 1.43, respectively. A strong correlation coefficient was found between ASL nTBF and DSC nTBF with contralateral GM as the reference region (r = 0.903; R2= 0.813). Mean DSC nTBF and DSC nTBV also showed a strong correlation (r = 0.83; R2= 0.701). It was concluded that the measurement of CBF from ASL is a form of noninvasive assessment of blood flow in intracranial tumors as an alternative to DSC MRI.[31]

Lee et al (2019) did a retrospective study using DSC-MR imaging of treatment naïve and histopathology-proven cases of GBM (14), primary central nervous system lymphomas (7), metastasis (20), and meningiomas (13). The study was done using a protocol designed for relative CBV accuracy. Mean PSR, rCBV, and normalized baseline signal intensity were compared within the contrast-enhancing lesions. It was found that rCBV best-differentiated meningioma from GBM and metastasis. PSR best differentiated PCNL from metastasis. rCBV and PSR were similar in differentiating PCNL from GBM and meningioma. Although rCBV and PSR did not help differentiate glioblastoma from metastasis, mean normalized baseline signal intensity achieved 86% sensitivity and 50% specificity.[32]

Surendra et al (2020) conducted a study including pathologically confirmed cases of 10 low-grade gliomas, 22 high-grade gliomas, 6 lymphomas, and 12 metastasis (Total 50). PSR, rPSR, and rCBV were calculated. For normalization contralateral white matter was used. rCBV was higher in metastasis and high-grade glioma, whereas it was low in lymphoma and low-grade glioma with p-value of 0.030. PSR was low in metastasis, intermediate in glioma, and high in lymphoma with p-value < 0.000. rPSR was higher for lymphoma than high-grade glioma and metastasis with p-value <.000. Area under ROC was greater for PSR than rCBV in differentiating metastasis from lymphoma, high-grade glioma from lymphoma, high-grade glioma from metastasis and

high-grade glioma from low-grade glioma with excellent curve characteristics. F values for PSR and rPSR from ANOVA analysis were better than rCBV in differentiating these groups. Thus, PSR shows low recovery values in metastasis, intermediate recovery values in glioma, and overshoot in lymphoma. PSR values show lower overlap than rCBV between lymphoma and metastasis; and between high-grade glioma and metastasis. PSR difference is also higher than rCBV between low- and high-grade gliomas. Hence, PSR can potentially help as an additional perfusion parameter in the pre-operative differentiation of these tumors.[33]

Cindil et al (2021) evaluated 99 solitary-enhancing intracranial tumors (60 HGGs, 24 metastasis, and 15 PCNSLs), which were retrospectively assessed before treatment. rCBV, PSR, and ADC values in the tumor core and rCBV and ADC values in peritumoral edema were measured. For normalization contralateral white matter was used. The differences were evaluated using one-way ANOVA, and the diagnostic performance was evaluated using ROC curve analysis. It was concluded that PSR in the tumor core showed better results in differentiating these three tumor types.[34]

MATERIALS AND METHODS

SOURCE OF DATA

A prospective study was conducted over a period of one and a half years, from 15th September 2022 to 15th March 2024 on patients referred to our institution, Dayanand Medical College and Hospital for MR Brain in the Department of Radiodiagnosis, with clinical suspicion of brain tumor.

METHOD OF COLLECTION OF DATA

This prospective study was done on patients who were referred to the Department of Radiodiagnosis, Dayanand Medical College and Hospital for MRI Brain, with clinical suspicion of brain tumor for one and a half years starting from 15th September 2022 to 15th March 2024. Only enhancing intra-axial brain lesions were included in the study.

INCLUSION CRITERIA:

1. Imaging evidence of enhancing intra-axial brain tumor.

EXCLUSION CRITERIA:

1. Patients on chemotherapy/ radiotherapy.
2. Post-operative cases.
3. Patients with alternative diagnosis.
4. Patients who refused to participate in the study.

MRI PROTOCOL:

MR imaging was performed on a 3 T MR Scan machine (Magnetom Skyra, Siemens, Germany) with a quadrature matrix head coil. Conventional sequences which were included are DWI (Resolve) axial, T2 TSE dark fluid transverse, SWI transverse, T2 TSE transverse, T1 TSE dark fluid, T2 TSE coronal and T2 TSE sagittal. These sequences were followed by contrast administration and post-contrast sequences which included T2 weighted echo planar imaging sequence (Ep2d_perf), T1 SE transverse fat sat post-contrast, and T1 MP-RAGE transverse post-contrast 3d. After post-contrast sequences, spectroscopy csi-se 135 was performed.

The paramagnetic gadolinium-based contrast material was injected intravenously through an 18- or 20-gauge needle manually with a dose of 0.2 mmol/kg, followed by a 10 ml bolus of saline. All perfusion data was transferred to a stand-alone workstation for post-processing on a diagnostic color display system using a dedicated advanced software package- SYNGOVIA MR Perfusion Software.

The sequences were obtained with the following parameters:

Table 1: MRI acquisition parameters

Sequence	DWI (Resolve) Axial	T2 TSE Dark fluid Transverse	SWI Transverse	T2 TSE Transverse	T1 TSE Dark Fluid	T2 TSE Coronal	T2 TSE Sagittal	Ep2d_ Perf	T1 SE Transverse Fat Sat	T1 MP-RAGE Transverse 3D
Acquisition time	2.03 min	2.08 min	1.28 min	1.28 min	1.42 min	1.51 min	1.42 min	1.42 min	2.48 min	5.38 Min
Orientation	Transverse	Transverse	Transverse	Transverse	Transverse	Coronal	Sagittal	Transverse	Transverse	Transverse
Resolution Matrix	160* 100	320* 81	256* 80	512* 60	320* 91	512* 65	384* 75	128* 100	256* 70	256* 100
No. of slices	27	27	40/slab	28	28	25	25	20	25	176/ slab
FoV Read (mm)	220	220	220	220	220	220	230	220	220	230
FoV Phase (%)	100	87.5	90.6	87.5	87.5	87.5	100	100	84.4	100
Slice Thickness (mm)	4	4	3.5	4	4	4	4	4	4	1
Slice Gap (mm)	1.2	1.2	-	1.2	1.2	1.5	1.5	1.2	1.2	-
Repetition Time (msec)	5500	9000	27	5060	2000	5200	5270	1600	533	2200
TE (msec)	64	81	20	91	9	96	92	30	17	2.48
Flip Angle	180	130	15	120	150	150	140	90	58	8
Flow Compression	-	No	Yes	Read	No	Read	Read	-	Yes	No

IMAGING PROCESSING AND DATA ANALYSIS:

Data processing was performed on a workstation using SYNGOVIA MR Perfusion software for image analysis.

ROI PLACEMENT:

1. ROI PLACEMENT FOR CBV AND CBF:

From processed perfusion images, color-coded CBV and CBF maps were obtained. For maximum CBV and CBF values for each lesion, multiple regions of interest (ROI) of 25-40 mm^2 were drawn on the enhancing solid portion of the lesion. Maximum CBV and CBF values were chosen and were normalized by drawing ROI on the contralateral normal gray matter.

rCBV and rCBF values were obtained by dividing maximum lesion CBV and CBF by normalized CBV and CBF.

2. ROI PLACEMENT FOR PERCENTAGE SIGNAL RECOVERY:

To obtain a signal intensity curve, multiple ROI of 25-40 mm^2 were manually drawn on the post-contrast T1WI at the enhancing solid portion of the lesion. Areas of necrosis or hemorrhage were carefully excluded. The highest recovered signal intensity curve was selected to calculate the Percentage signal recovery (PSR).

The PSR was calculated using the formula:

Percentage signal recovery (PSR) = 100% x [S1 – Smin] | [S0 – Smin]
Where S1 is post-contrast T2 weighted signal intensity, S0 is pre-contrast T2 weighted signal intensity and Smin is minimum T2 weighted signal intensity.

For normalization, free hand ROI was drawn on the contralateral normal gray matter and rPSR [rPSR = highest lesion PSR | normalized PSR] was calculated.

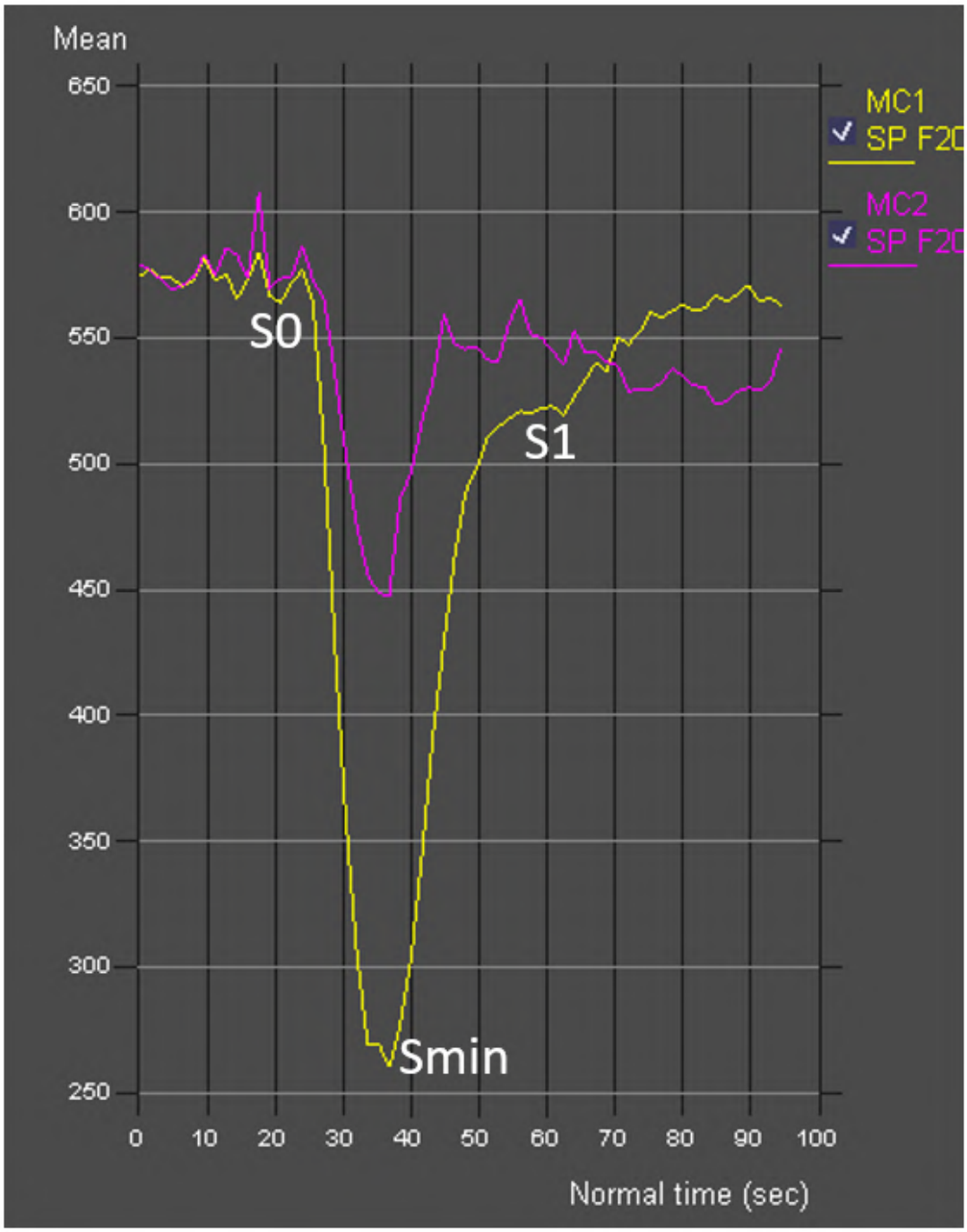


Figure 1: Sample signal intensity curve

DURATION OF STUDY:

The study was conducted over a period of 1 and a half years.

OUTCOME:

Performance of Perfusion Parameters and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in differentiation of common enhancing intra-axial brain tumors were evaluated.

STATISTICAL ANALYSIS:

Data will be described in terms of range; mean +/- standard deviation (+/- SD), median, frequencies (number of cases), and relative frequencies (percentages) as appropriate. A receiver operator characteristics (ROC) curve will be done, and the criterion value will be estimated depending on the specificity and sensitivity. A probability value (p-value) less than 0.05 will be considered statistically significant. All statistical calculations will be done using (Statistical Package for the Social Science) SPSS 21 version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft Windows.

OBSERVATIONS AND RESULTS

1. DEMOGRAPHIC DATA

A total of 50 cases with enhancing intra-cranial lesions were included in the study. The age range of patients was from 23-85 years as shown in Table 2, Figure 2. The study included 25 females and 25 males as shown in Table 3, Figure 3.

Table 2: Age distribution

Age	No. of cases	Percentage
< 40	4	8.0%
41-50	10	20.0%
51-60	13	26.0%
61-70	15	30.0%
> 70	8	16.0%
Total	50	100.0%

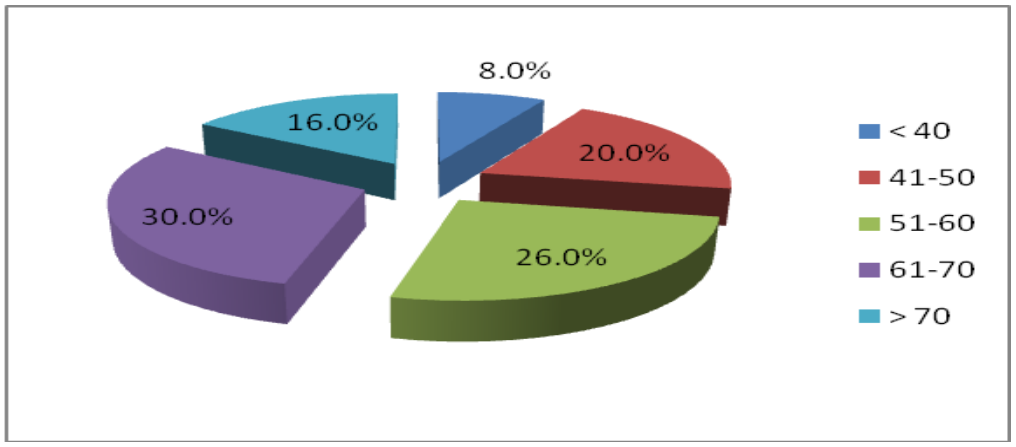


Figure 2: Pie chart showing age group distribution (years) with percentage of cases in the respective age group

Table 3: Gender distribution

Sex	No. of cases	Percentage
F	25	50.0%
M	25	50.0%
Total	50	100.0%

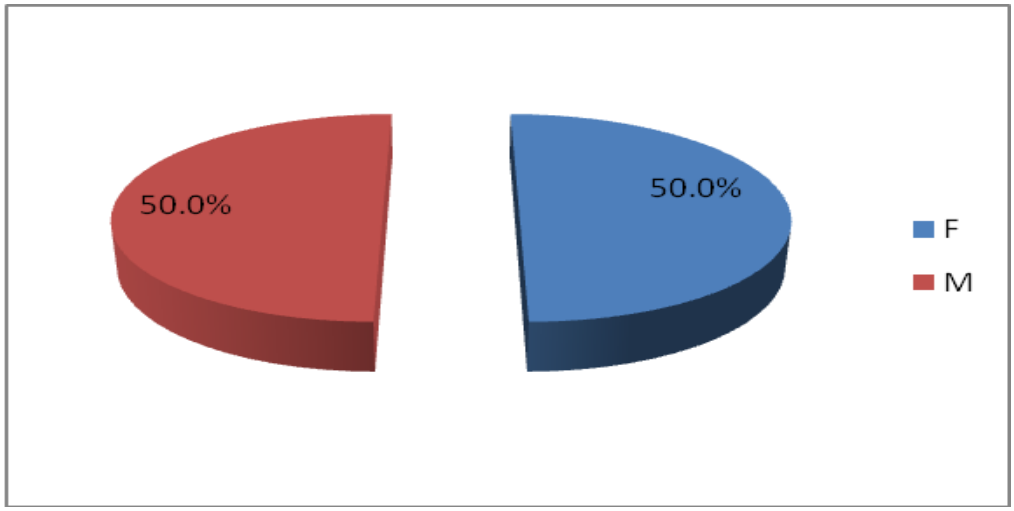


Figure 3: Pie chart showing the distribution of males and females

2. CLINICAL PRESENTAION

Chief presenting complaints were headache (60%), nausea (6%), vomiting (8%), vertigo (18%), paralysis/paresis (32%), and seizures (34%) as shown in Table 4, Figure 4.

Table 4: Clinical presentation

Chief complaints	No. of cases	Percentage
Headache	30	60.0%
Nausea	3	6.0%
Vomiting	4	8.0%
Vertigo	9	18.0%
Paralysis/Paresis	16	32.0%
Seizure	17	34.0%
Any other	11	22.0%

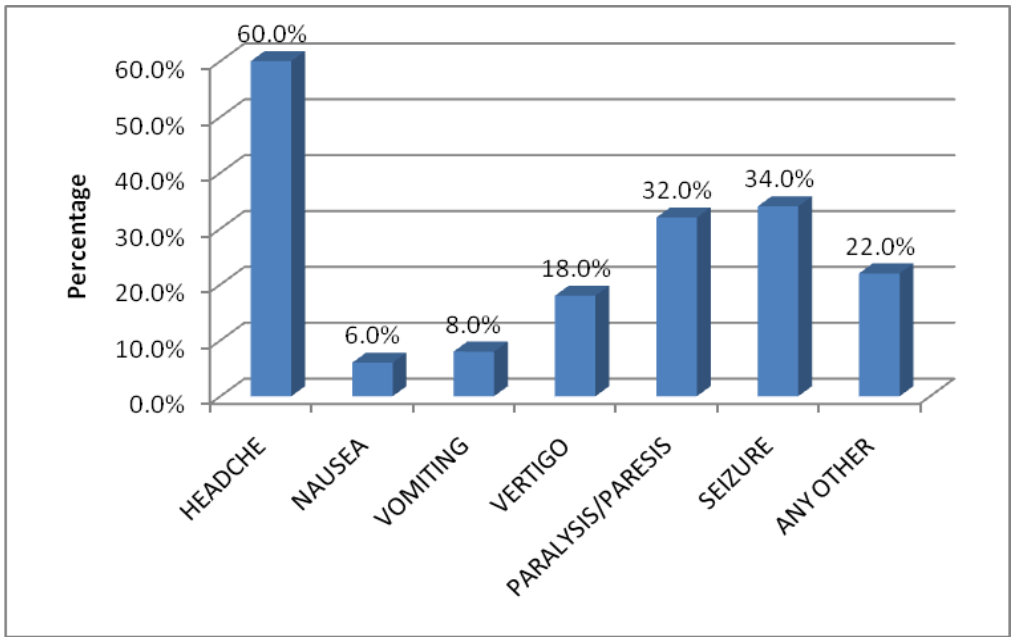


Figure 4: Clinical presentation

3. TUMOR DISTRIBUTION

All patients had newly detected brain lesions. Tissue for histopathological analysis was obtained at biopsy or during surgical resection of the lesion. Histopathological assessment was done in 41 out of 50 cases and revealed 11 cases of diffuse large B-cell lymphomas, 28 cases of high-grade gliomas, and 2 cases of metastasis. 9 cases did not undergo histopathological examination as they had a known primary tumor. In these cases, multifocal lesions were present with MRI findings consistent with metastatic lesions. The distribution of tumor subtypes in all cases is shown in Table 5, Figure 5.

Table 5: Distribution of tumor subtypes

Tumor	No. of cases	Percentage
Diffuse large B-cell lymphoma	11	22%
High-grade glioma	28	56%
Metastasis	11	22%
Total	50	100.0%

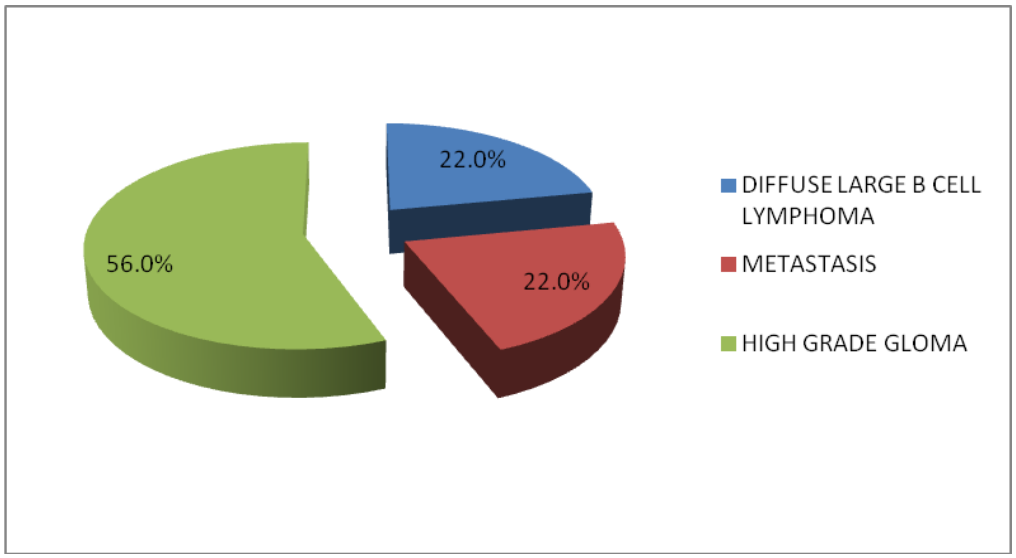


Figure 5: Pie chart showing the distribution of tumor subtypes and percentage of cases in each group

4. QUANTITATIVE PERFUSION PARAMETERS

Quantitative perfusion parameters including rCBV, rCBF, PSR, and rPSR were calculated.

Quantitative perfusion parameters in diffuse large B-cell lymphoma:

Quantitative perfusion parameters including rCBV, rCBF, PSR, and rPSR were calculated in diffuse large B-cell lymphoma with mean values as shown in Table 6.

11 cases of diffuse large B-cell lymphoma included in our study revealed mean rCBV value of 1.67 ± 0.36, mean rCBF value of 1.51 ± 0.33, mean PSR value of 131.55 ± 19.87, and mean rPSR value of 1.47 ± 0.24

Table 6: Quantitative perfusion values (mean ± S.D.) in diffuse large B-cell lymphoma

rCBV	1.67 ± 0.36
rCBF	1.51 ± 0.33
PSR	131.55 ± 19.87
rPSR	1.47 ± 0.24

Quantitative perfusion parameters in high-grade glioma:

Quantitative perfusion parameters including rCBV, rCBF, PSR, and rPSR were calculated in high-grade glioma with mean values as shown in Table 7.

28 cases of high-grade glioma included in our study revealed mean rCBV value of 3.59 ± 0.91, mean rCBF value of 3.32 ± 0.75, mean PSR value of 77.25 ± 10.00, and mean rPSR value of 0.89 ± 0.08.

Table 7: Quantitative perfusion values (mean ± S.D.) in high-grade glioma

rCBV	3.59 ± 0.91
rCBF	3.32 ± 0.75
PSR	77.25 ± 10.00
rPSR	0.89 ± 0.08

Quantitative perfusion parameters in metastasis:

Quantitative perfusion parameters including rCBF, rCBF, PSR, and rPSR were calculated in metastasis with mean values as shown in Table 8.

11 cases of metastasis included in our study revealed mean rCBV value of 3.28 ± 1.12, mean rCBF value of 2.88 ± 0.86, mean PSR value of 57.64 ± 5.90, and mean rPSR value of 0.73 ± 0.07.

Table 8: Quantitative perfusion values (mean ± S.D.) in metastasis

rCBV	3.28 ± 1.12
rCBF	2.88 ± 0.86
PSR	57.64 ± 5.90
rPSR	0.73 ± 0.07

5. AREA UNDER ROC

Diffuse large B-cell lymphoma vs High-grade glioma

Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from high-grade glioma is shown in Table 9, Figure 6. Area under ROC for PSR was 1.000, rPSR was 0.992, rCBV was 0.003 and rCBF was 0.000 in differentiating diffuse large B-cell lymphoma from high-grade glioma with p-value of 0.001.

Area under ROC for PSR (1.000) and rPSR (0.992) was better than rCBV (0.003) and rCBF (0.000) in differentiating diffuse large B-cell lymphoma from high-grade glioma with excellent curve characteristics.

Table 9: Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from high-grade glioma

Test Result Variable(s)	Area	Std. Error [a]	p-value	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
rCBV	0.003	0.005	0.001	0.000	1.000
rCBF	0.000	0.000	0.001	0.000	0.000
PSR	1.000	0.000	0.001	0.000	1.000
rPSR	0.992	0.011	0.001	0.000	1.000

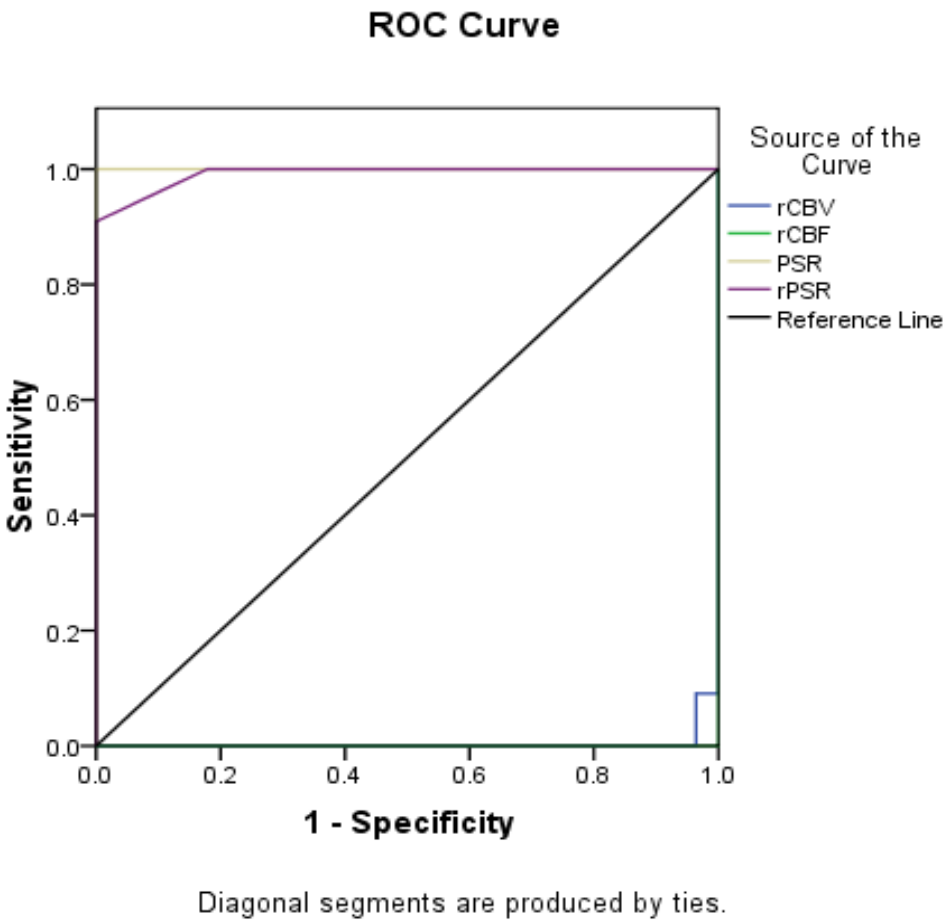


Figure 6: ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from high-grade glioma

High-grade glioma vs Metastasis

Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating HGG from metastasis is shown in Table 10, Figure 7. Area under ROC for PSR was 0.961, rPSR was 0.935, rCBV was 0.609 and rCBF was 0.631 in differentiating high-grade glioma from metastasis with a statistically significant p-value of 0.001 for PSR and rPSR.

Area under ROC for PSR (0.961) and rPSR (0.935) was better than rCBV (0.609) and rCBF (0.631) in differentiating high-grade glioma from metastasis with excellent curve characteristics.

Table 10: Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating high-grade glioma from metastasis

Test Result Variable(s)	Area	Std. Error [a]	p-value	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
rCBV	0.609	0.119	0.296	0.376	0.842
rCBF	0.631	0.115	0.206	0.406	0.857
PSR	0.961	0.027	0.001	0.000	1.000
rPSR	0.935	0.037	0.001	0.849	1.000

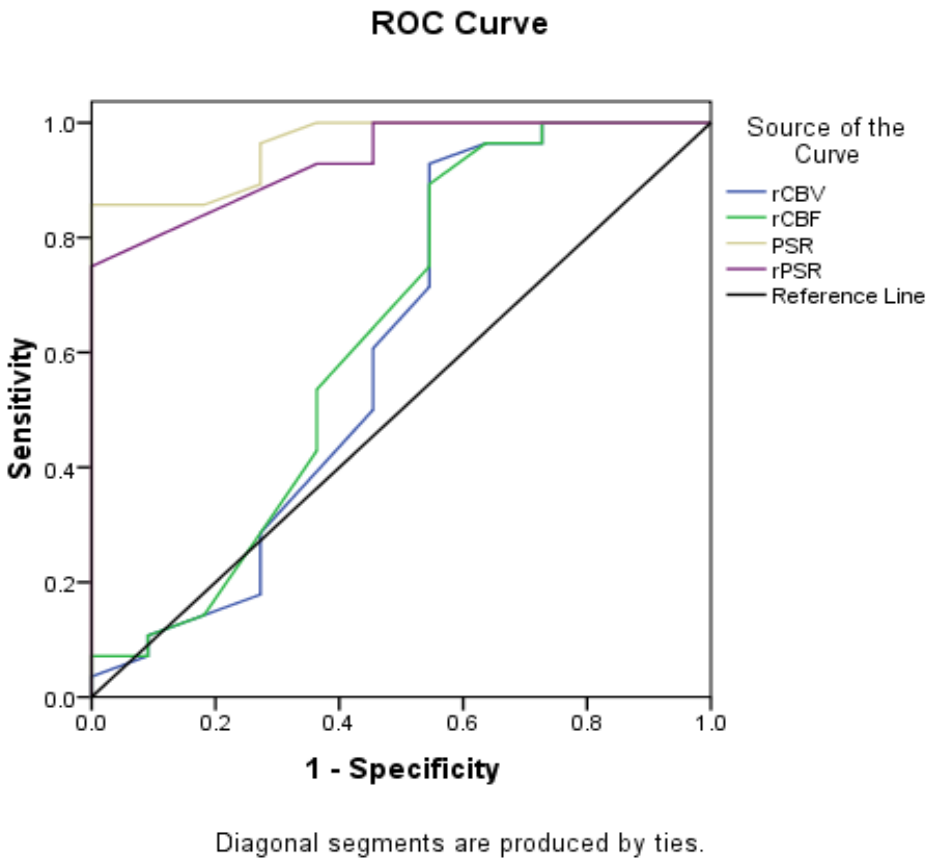


Figure 7: ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating high-grade glioma from metastasis

Diffuse large B-cell lymphoma vs Metastasis

Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from metastasis is shown in Table 11, Figure 8. Area under ROC for PSR was 1.000, rPSR was 1.000, rCBV was 0.029 and rCBF was 0.054 in differentiating diffuse large B-cell lymphoma from metastasis with p-value of 0.001.

Area under ROC for PSR (1.000) and rPSR (1.000) was better than rCBV (0.029) and rCBF (0.054) in differentiating diffuse large B-cell lymphoma from metastasis with excellent curve characteristics.

Table 11: Area under ROC for rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from metastasis

Test Result Variable(s)	Area	Std. Error [a]	p-value	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
rCBV	0.029	0.031	0.001	0.000	1.000
rCBF	0.054	0.046	0.001	0.000	1.000
PSR	1.000	0.000	0.001	1.000	1.000
rPSR	1.000	0.000	0.001	1.000	1.000

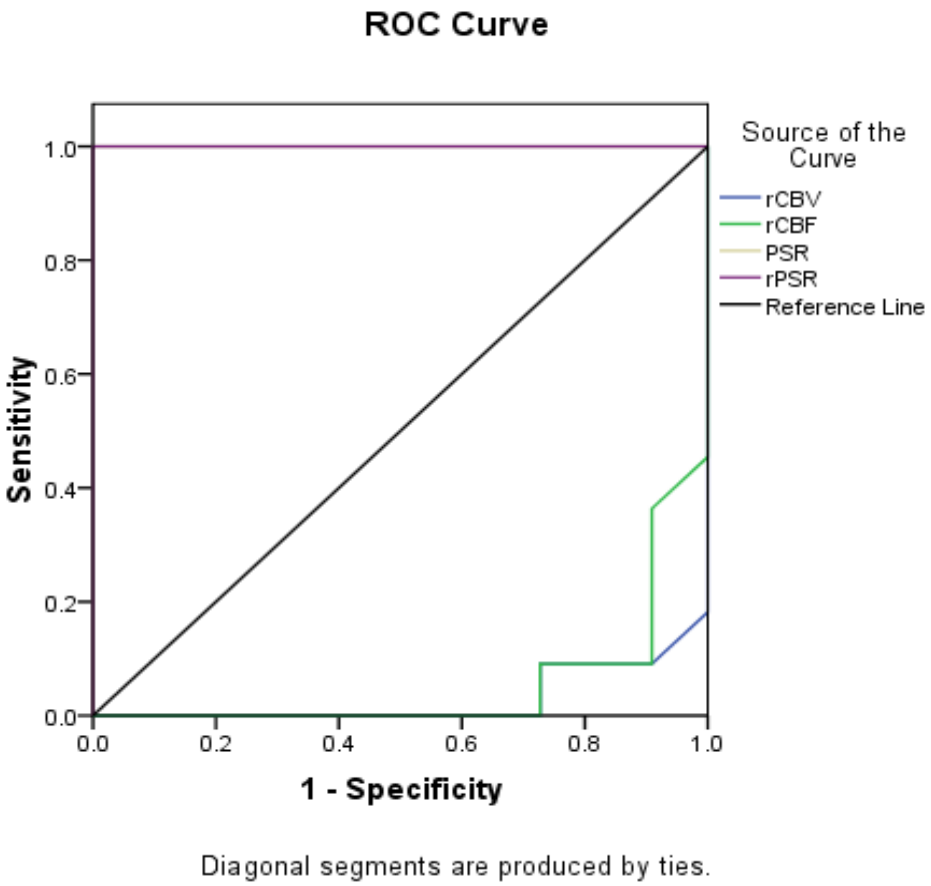


Figure 8: ROC for comparison of rCBV, rCBF, PSR, and rPSR for differentiating diffuse large B-cell lymphoma from metastasis

6. F-STATISTIC OBTAINED FROM ONE WAY ANOVA

ANOVA F-test value for PSR was 113.323, for rPSR was 108.744, for rCBV was 19.027, and for rCBF was 25.487 in differentiating the 3 groups with significant p-values as shown in Table 12.

Table 12: F-statistic obtained from one way ANOVA

Perfusion parameters		Mean Square	F (ANOVA F statistic)	Significance (p-value)
rCBV	Between Groups	14.738	19.027	0.001
	Within Groups	0.775		
rCBF	Between Groups	12.942	25.487	0.001
	Within Groups	0.508		
PSR	Between Groups	16874.379	113.323	0.001
	Within Groups	148.905		
rPSR	Between Groups	1.808	108.744	0.001
	Within Groups	0.017		

7. Boxplots depicting variations in the rCBV, rCBF, PSR, and rPSR

Boxplots depicting variations in the rCBV, rCBF, PSR, and rPSR in differentiating the three groups are shown in Figures 9, 10, 11 and 12. The solid line inside the box indicates the median value with edges representing the 25^{th} and 75^{th} percentiles. The straight line that is the black line in each box represents a range of data distribution. Solid black circles represent outliers.

Overlap of rCBV and rCBF values was noted among high-grade glioma and metastasis as depicted in Figure 9, Figure 10.

No significant overlap of PSR and rPSR values among the three groups was noted as depicted in Figure 11, Figure 12.

High PSR and rPSR values were noted in case of diffuse large B-cell lymphoma.

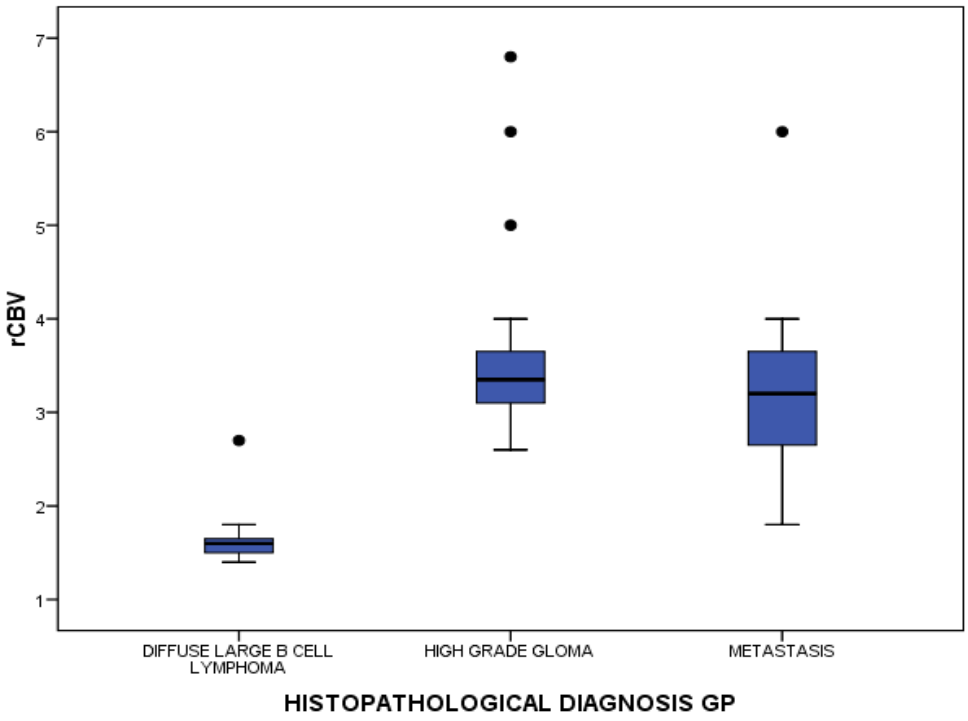


Figure 9: Boxplot depicting variations in rCBV in differentiating the three groups

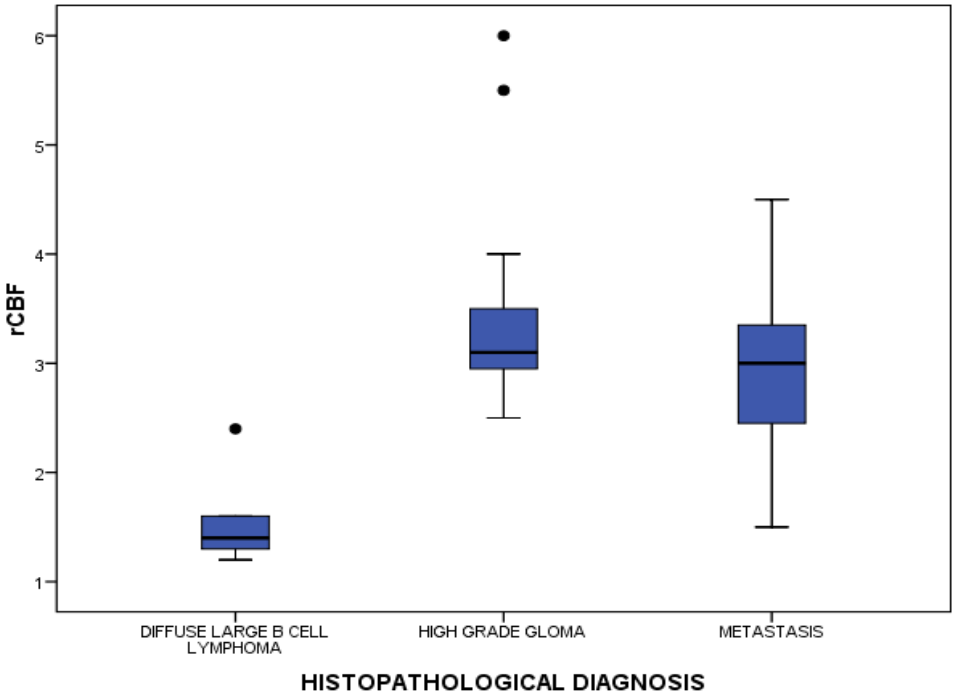


Figure 10: Boxplot depicting variations in rCBF in differentiating the three groups

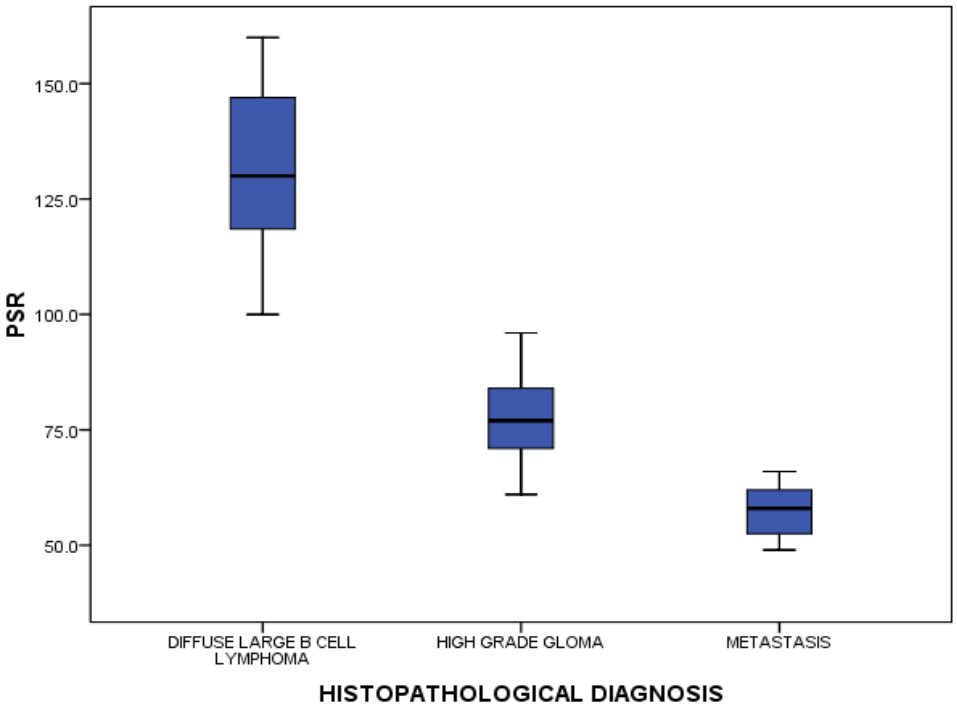


Figure 11: Boxplot depicting variations in PSR in differentiating the three groups

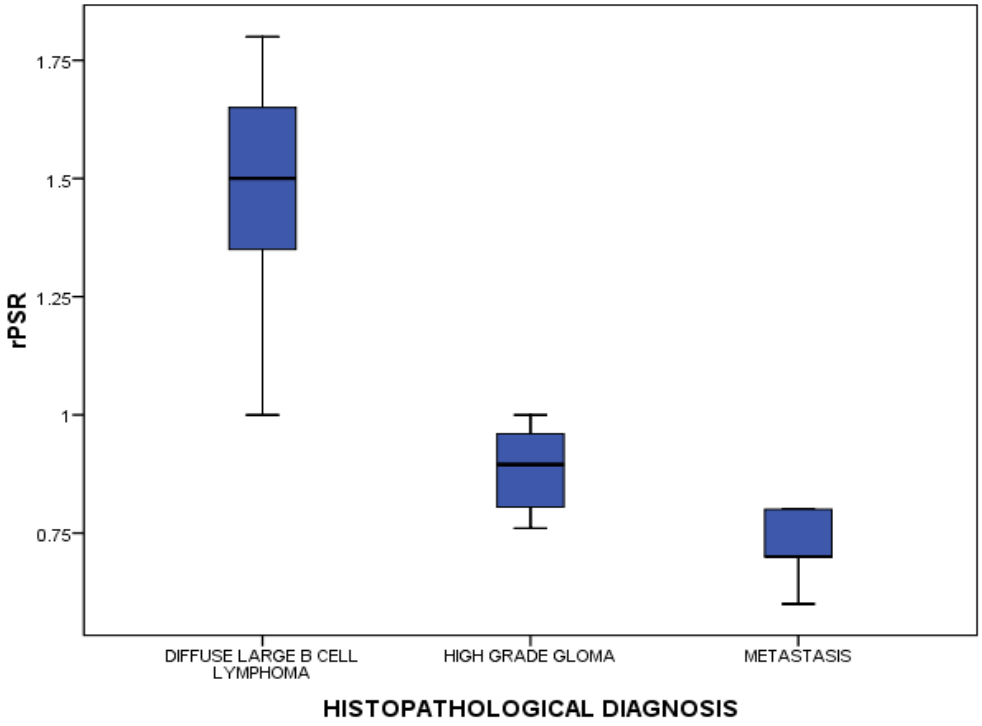


Figure 12: Boxplot depicting variations in rPSR in differentiating the three groups

DISCUSSION

MR perfusion imaging refers to the techniques used to measure cerebral perfusion via assessment of various hemodynamic measurements such as cerebral blood volume, cerebral blood flow, and mean transit time. It is a sensitive method to study the microvasculature and is non-invasive.

Two main approaches have been developed for perfusion MRI. One approach uses an exogenous contrast agent. Other approach is without the use of an exogenous contrast agent. Dynamic susceptibility contrast (DSC)-MRI and dynamic contrast-enhanced (DCE)-MRI are included in the first group. The second group includes arterial spin-labeling (ASL).

DSC-MRI is used for evaluating the perfusion in cerebral ischemia as well as in brain tumors. In this method rapid intravenous injection of MR contrast agent is followed by serial measurement of signal loss during the passage of bolus through the tissue, using T2 or $T2^{*}$WI.

DCE-MRI is another method that also relies on the intravenous injection of a contrast agent. Here, T1WI are acquired dynamically before, during, and after bolus injection of the contrast agent. The data is then interpreted in terms of physiological tissue characteristics by applying the physical principles of tracer-kinetic modeling.

ASL quantitatively measures cerebral perfusion, also referred to as CBF. It takes advantage of magnetically labeled blood as an endogenous tracer.

DSC MR imaging assesses the neovascularity and capillary permeability of the lesion. rCBV and rCBF reflect neovascularity of the lesion and do not provide much information regarding the capillary permeability, whereas PSR reflects an interplay of both capillary density as well as capillary permeability.

PSR is a promising parameter obtained from T2* DSC MR imaging. It can be used as a problem-solving tool in addition to rCBV and rCBF, especially in situations where there are similarities in the imaging characteristics of brain tumors on standard MR sequences. It is simple to calculate and does not require elaborate post-processing applications.[3-4,30] PSR demonstrates distinct recovery characteristics as compared to rCBV and rCBF. Overshoot from the baseline or a high PSR was seen in diffuse large B-cell lymphoma, intermediate PSR was seen in high-grade glioma, and low PSR was seen in metastasis.

Our study demonstrates evidence supporting that perfusion parameters like rCBV, rCBF, PSR, and rPSR can help differentiate between DLBCL, HGG, and metastasis when there are similarities in their imaging appearances on conventional MR sequences. Histopathologically there are significant differences in the vascular morphology and neoangiogenesis of these tumors.

HGG is characterized by severe cellular atypia, vascular hyperplasia, glomeruloid capillaries, and blood-brain barrier disruption.

DLBCL on the other hand has distinct histological features of angiogenic growth pattern in which tumor cells cluster around the preexisting brain vessels and also widen the perivascular spaces leading to massive leak.[35-37]

The capillaries in the metastatic lesions are similar to the capillaries of the primary malignancy with prominent endothelial gaps and absence of blood-brain barrier components resulting in higher capillary permeability,[9,38-39] but the perivascular spaces may not be widened depending on the cellularity and hence modify the signal changes due to “wash in” and “wash out” effects.

Our study was supported by the studies done by Mangla et al [3], Surendra et al [33], and Cindil et al.[34] A comparison of various perfusion parameters in these studies and in the present study is shown in Tables 13, 14, and 15.

Table 13: Mean values and standard deviations of perfusion parameters in diffuse large B-cell lymphoma in the previous studies compared with the present study

Authors	No. of cases	rCBV	rCBF	PSR	rPSR
Present study	11	1.67 ± 0.36	1.51 ± 0.33	131.55 ± 19.87	1.47 ± 0.24
Mangla et al [3]	22	2.43 ± 1.19	-	113.15 ± 41.59	-
Surendra et al [33]	6	1.03 ± 0.74	-	112.12 ± 10.57	1.73 ± 0.57
Cindil et al [34]	15	1.51 ± 0.45	-	164.05 ± 37.0	1.81 ± 0.39

Table 14: Mean values and standard deviations of perfusion parameters in high-grade glioma in the previous studies compared with the present study

Authors	No. of cases	rCBV	rCBF	PSR	rPSR
Present study	28	3.59 ± 0.91	3.32 ± 0.75	77.25 ± 10.00	0.89 ± 0.08
Mangla et al [3]	22	4.72 ± 2.19	-	78.22 ± 14.27	-
Surendra et al [33]	22	3.47 ± 1.62	-	73.23 ± 6.39	0.85 ± 0.11
Cindil et al [34]	60	4.01 ± 2.51	-	95.30 ± 20.12	1.16 ± 0.59

Table 15: Mean values and standard deviations of perfusion parameters in metastasis in the previous studies compared with the present study

Authors	No. of cases	rCBV	rCBF	PSR	rPSR
Present study	11	3.28 ± 1.12	2.88 ± 0.86	57.64 ± 5.90	0.73 ± 0.07
Mangla et al [3]	22	2.93 ± 1.18	-	53.46 ± 12.87	-
Surendra et al [33]	12	3.45 ± 2.82	-	48 ± 16.18	0.69 ± 0.19
Cindil et al [34]	24	4.25 ± 3.05	-	59.83 ± 15.21	0.71 ± 0.20

In a study done by Xing et al [29], a total of 12 patients with DLBCL and 26 patients with HGG were evaluated. The average percentage of signal intensity recovery was significantly greater in DLBCL (137 ± 59%) than in HGG (68 ± 21%) with a p-value < 0.001 similar to the observations in our study.

In a study by Goyal et al [30], the mean rCBV value was 1.22 ± 0.32 in DLBCL, 4.32 ± 1.23 in glioblastoma multiforme, and 2.7 ± 1.25 in metastasis which is in concordance with the findings in our study.

Lee et al [32] reported that PSR was better than rCBV in differentiating DLBCL from metastasis. rCBV and PSR performed similarly in differentiating DLBCL from glioblastoma multiforme. Glioblastoma multiforme and metastasis were poorly differentiated by rCBV but were better distinguished by normalized baseline SI similar to the observations in our study.

Hartmann et al [10] conducted a study evaluating 12 cases of DLBCL and 12 cases of HGG. The mean maximum relative regional CBV ratio in DLBCL was 1.29 ± 0.18 and in glioblastoma multiforme was 4.99 ± 2.1 which is in concordance with our study.

In a study done by Soni et al [31] mean rCBF was 1.66 ± 1.48 in gliomas. The study included both low and high-grade gliomas. A total of 8 cases of gliomas were evaluated.

Jarnum et al [26] conducted a prospective study in which 19 cases of HGG were evaluated. Mean rCBF was 2.24 ± 1.37.

Differentiation of diffuse large B-cell lymphomas from high-grade gliomas

The preoperative diagnosis of DLBCL is important as it can avoid the use of extensive unnecessary surgery for tumor removal and can help in limiting the surgical procedure to a smaller biopsy which is important for tissue characterization necessary for treatment decisions.[40-42] It is important to recognize DLBCL on imaging because the administration of steroids in patients with brain tumors before a histopathological diagnosis can affect the diagnostic yield of resection or stereotactic biopsy.[43-44] Steroid treatment preceding biopsy can obscure the diagnosis of DLBCL in up to 50% of cases.

DLBCL is relatively avascular and demonstrates homogenous contrast enhancement on standard MRI due to lack of BBB and thus can simulate other vascular tumors like HGG and metastasis resulting in a diagnostic dilemma. The presence of hemorrhage or necrosis on preoperative imaging in immunocompetent patients has been considered a factor against the diagnosis of lymphoma,[45] but in recent literature hemorrhage can be present on imaging in upto 50% of patients and necrosis leading to heterogeneous or ring enhancement can be seen in about 10-15% of cases.

In our study, mean rCBV and rCBF were found to be on the lower side for diffuse large B-cell lymphoma than high-grade glioma due to lack of neoangiogenesis. Mean rCBV and rCBF values in DLBCL were 1.67 ± 0.36 and 1.51 ± 0.33. Mean rCBV and rCBF values in HGG were 3.59 ± 0.91 and 3.32 ± 0.75.

Mean rCBV value in DLBCL was 2.43 ± 1.19 and in HGG was 4.72 ± 2.19 in study done by Mangla et al.[3] Mean rCBV value in DLBCL was 1.03 ± 0.74 and in HGG was 3.47 ± 1.62 in study done by Surendra et al.[33] Mean rCBV value in DLBCL was 1.51 ± 0.45 and in HGG was 4.01 ± 2.51 in study done by Cindil et al [34] In agreement with our study low mean rCBV value was seen in case of DLBCL.

In our study DLBCL showed a characteristic perfusion pattern with overshooting of signal intensity and high mean PSR values. Mean PSR and rPSR values in DLBCL were 131.55 ± 19.87 and 1.47 ± 0.24. Mean PSR and rPSR values in HGG were 77.25 ± 10.00 and 0.89 ± 0.08.

Mean PSR value in DLBCL was 113.15 ± 41.59 and in HGG was 78.22 ± 14.27 in study done by Mangla et al.[3] Mean PSR and rPSR values were 112.12 ± 10.57 and 1.73 ± 0.57 in DLBCL, and 73.23 ± 6.39 and 0.85 ± 0.11 in HGG in study done by Surendra et al.[33] Mean PSR and rPSR values were 164.05 ± 37.0 and 1.81 ± 0.39 in DLBCL, and 95.30 ± 20.12 and 1.16 ± 0.59 in HGG in study done by Cindil et al.[34] In agreement with our study overshooting above the baseline and high mean PSR value was seen in case of DLBCL.

The exact cause for this overshooting phenomenon is not fully understood and may be due to extravasation of gadolinium into the perivascular interstitial space and complex T1 and T2* effects. The T2* effect results in lower signal intensity recovery, whereas the T1 effect results in higher signal recovery. Possibly for DLBCL, the T1 effect is dominant over the T2* effect due to the accumulation of gadolinium in the interstitial space.

Other histological factors like the compact nature of cellularity, blood volume, and vascular permeability or interplay between these factors may also contribute to the high PSR.[10,46] Similar to the results published in studies done by Mangla et al [3], Surendra et al [33] , Cindil et al [34] and Xing et al [29] our study showed that PSR and rPSR can be used in addition to rCBV and rCBF for differentiation between DLBCL from HGG.

Differentiation of high-grade gliomas from metastasis

High-grade glioma and metastasis can have similar imaging appearances on standard MRI which is likely due to the similarity in histological nature that is secondary to high cellularity and neovascularity. A history of primary cancer and multiple lesions help differentiate metastatic lesions from HGG in patients with contrast-enhancing brain lesions. There is a diagnostic challenge especially when there is solitary metastasis.[47-48] Thus, differentiating between these two is becoming a challenging issue in patient care for neuroradiologists and neurosurgeons.[49-51] In many cases, a biopsy has to be performed for histopathological confirmation, even when there is a history of known malignancy.[52]

In our study, mean rCBV and rCBF were not found to be very useful for the differentiation of HGG from metastasis because of overlapping values. Mean rCBV and rCBF values in HGG were 3.59 ± 0.91 and 3.32 ± 0.75. Mean rCBV and rCBF values in metastasis were 3.28 ± 1.12 and 2.88 ± 0.86.

Mean rCBV in HGG was 4.72 ± 2.19 and in metastasis was 2.93 ± 1.18 in study done by Mangla et al.[3] Mean rCBV value in HGG was 3.47 ± 1.62 and in metastasis was 3.45 ± 2.82 in study done by Surendra et al.[33] Mean rCBV in HGG was 4.01 ± 2.51 and in metastasis was 4.25 ± 3.05 in study done by Cindil et al.[34] In agreement with our study overlapping of mean rCBV values were seen in cases of HGG and metastasis.

In our study the signal intensity recovery pattern was helpful for the differentiation of HGG from metastasis with intermediate mean PSR for HGG (77.25 ± 10.00) and low mean PSR for metastasis (57.64 ± 5.90). Mean rPSR value in the case of HGG was 0.89 ± 0.08 and for metastasis was 0.73 ± 0.07.

Mean PSR value in HGG was 78.22 ± 14.27 and in metastasis was 53.46 ± 12.87 in study done by Mangla et al.[3] Mean PSR and rPSR values were 73.23 ± 6.39 and 0.85 ± 0.11 in HGG, and 48 ± 16.18 and 0.69 ± 0.19 in metastasis in study done by Surendra et al.[33] Mean PSR and rPSR values were 95.30 ± 20.12 and 1.16 ± 0.59 in HGG, and 59.83 ± 15.21 and 0.71 ± 0.20 in metastasis in study done by Cindil et al.[34]

The capillaries in metastasis resemble those of the original systemic cancer and thus have no similarity to the normal brain capillaries. Metastasis has prominent capillary fenestrations and absence of BBB components which in return produces a pronounced T2* effect resulting in a low signal intensity recovery, whereas in cases of HGG lesser capillary fenestration and partial disruption of BBB components produces a moderate T2* effect resulting in intermediate signal intensity recovery. These results are similar to previous studies done by Mangla et al [3] , Surendra et al [33] , and Cindil et al.[34]

Differentiation of diffuse large B-cell lymphoma from metastasis

A solitary metastatic lesion presenting as an enhancing mass lesion might be the first manifestation of a systemic malignancy.[48] It is thus difficult to differentiate solitary metastasis from other enhancing lesions on contrast-enhanced MR imaging.

In our study, mean rCBV and rCBF values were found useful for the differentiation of diffuse large B-cell lymphoma from metastasis. The mean value of rCBV was 1.67 ± 0.36 and rCBF was 1.51 ± 0.33 in DLBCL. The mean value of rCBF was 3.28 ± 1.12 and rCBF was 2.88

± 0.86 in case of metastasis. DLBCL has low mean rCBV and rCBF values.

Mean rCBV value in DLBCL was 2.43 ± 1.19 and in metastasis was 2.93 ± 1.18 in study done by Mangla et al.[3] Mean rCBV value in DLBCL was 1.03 ± 0.74 and in metastasis was 3.45 ± 2.82 in study done by Surendra et al.[33] Mean rCBV value in DLBCL was 1.51 ± 0.45 and in metastasis was 4.25 ± 3.05 in study done by Cindil et al.[34] Supporting our study DLBCL has low mean rCBV value.

In our study the signal intensity recovery pattern was also helpful in differentiating DLBCL from metastasis with high mean PSR for DLBCL (131.55 ± 19.87) and low mean PSR for metastasis (57.64 ± 5.90). Mean rPSR values for DLBCL were 1.47 ± 0.24 and for metastasis were 0.73 ± 0.07.

Mean PSR value in DLBCL was 113.15 ± 41.59 and in metastasis was 53.46 ± 12.87 in study done by Mangla et al.[3] Mean PSR and rPSR values were 112.12 ± 10.57 and 1.73 ± 0.57 in DLBCL, and 48 ± 16.18 and 0.69 ± 0.19 in metastasis in study done by Surendra et al.[33] Mean PSR and rPSR values were 164.05 ± 37.0 and 1.81 ± 0.39 in DLBCL, and 59.83 ± 15.21 and 0.71 ± 0.20 in metastasis in study done by Cindil et al.[34] In agreement with our study overshooting above the baseline and high mean PSR values were seen in DLBCL.

Perfusion parameters derived from DSC MRI imaging have many advantages. They serve as noninvasive methods which do not use radiation or radioisotopes. These methods can be applied to the diagnosis and grading of cerebral tumors, distinguishing tumor recurrence from radiation necrosis, and evaluating the response to therapy as well as prognosis. PSR and rPSR are quite simple to calculate and do not require elaborate post-processing. These methods can also be used in monitoring and follow-up of these patients. PSR is a novel parameter that when combined with rCBV and rCBF can improve the diagnostic yield in pre-operative differentiation of these

tumors. PSR shows high recovery values in case of DLBCL with overshooting above the baseline, intermediate recovery values in case of HGG, and low recovery values in case of metastasis. PSR and rPSR values had better diagnostic performance than rCBV and rCBF in differentiating between HGG and metastasis. Thus, in addition to rCBV and rCBF, PSR and rPSR can be employed in routine imaging of brain tumors.

LIMITATIONS

One of the limitations of our study was a small sample size. 9 cases of metastasis were without biopsy and were diagnosed as metastasis on the basis of primary tumor elsewhere. Some technical limitations exist as well. For instance, the presence of hemorrhage or susceptibility artifacts may render errors in the calculation of rCBV, rCBF, and signal intensity recovery. Various perfusion parameters can be affected by the MR imaging acquisition protocol. In our study, we used a very strict and consistent imaging protocol for all tumors studied, including TR, TE, field strength, spatial resolution, flip angle, and dose of contrast agent administered.

SUMMARY AND CONCLUSIONS

1.50 patients with intra-cranial enhancing lesions were included in our study. Out of 50, 28 cases were of high-grade gliomas, 11 cases were of metastasis, and 11 cases were of diffuse large B-cell lymphomas.

2.In DLBCL mean rCBV value was 1.67 ± 0.36, mean rCBF value was 1.51 ± 0.33, mean PSR value was 131.55 ± 19.87, and mean rPSR value was 1.47 ± 0.24.

3.In HGG mean rCBV value was 3.59 ± 0.91, mean rCBF value was 3.32 ± 0.75, mean PSR value was 77.25 ± 10.00, and mean rPSR value was 0.89 ± 0.08.

4.In metastasis mean rCBV value was 3.28 ± 1.12, mean rCBF value was 2.88 ± 0.86, mean PSR value was 57.64 ± 5.90, and mean rPSR value was 0.73 ± 0.07.

5. Area under ROC for PSR (1.000) and rPSR (0.992) was better than rCBV (0.003) and rCBF (0.000) in differentiating DLBCL from HGG.

6. Area under ROC for PSR (0.961) and rPSR (0.935) was better than rCBV (0.609) and rCBF (0.631) in differentiating HGG from metastasis.

7. Area under ROC for PSR (1.000) and rPSR (1.000) was better than rCBV (0.029) and rCBF (0.054) in differentiating DLBCL from metastasis.

8. ANOVA F-test value for PSR was 113.323, for rPSR was 108.744, for rCBV was 19.027, and for rCBF was 25.487. These values were higher for PSR and rPSR than rCBV and rCBF in differentiating the 3 groups and with significant p-values.

9. There was an overlap of rCBV and rCBF values noted among HGG and metastasis. No significant overlap of PSR and rPSR values among the three groups was noted.

Percentage signal recovery (PSR) shows low recovery values in metastasis, intermediate recovery values in HGG, and overshoot in DLBCL. Hence, rPSR and PSR can potentially help as an additional perfusion parameter in addition to rCBV and rCBF in the preoperative differentiation of these tumors. PSR appears to be a simplified hemodynamic parameter that is clinically meaningful and effective in eliciting distinctive characteristics, which may help in differentiating these tumors when there are overlapping imaging findings.

BIBLIOGRAPHY

1. Jacobs AH, Kracht LW, Gossmann A, et al. Imaging in neurooncology. NeuroRx 2005;2:333–347.
2. Stadnik TW, Demaerel P, Luypaert RR, et al. Imaging tutorial: differential diagnosis of bright lesions on diffusion-weighted MR images. Radiographics 2003;23: e7 Medline.
3. Mangla R, Kolar B, Zhu T, Zhong J, Almast J, Ekholm S. Percentage signal recovery derived from MR dynamic susceptibility contrast imaging is useful to differentiate common enhancing malignant lesions of the rain. AJNR Am J Neuroradiol 2011;32:1004-10.
4. Smitha KA, Gupta AK, Jayasree RS. Relative percentage signal intensity recovery of perfusion metrics—an efficient tool for differentiating grades of glioma. Br J Radiol 2015;88:20140784.
5. Essig M, Shiroishi MS, Nguyen TB et-al. Perfusion MRI: the five most frequently asked technical questions. AJR Am J Roentgenol. 2013;200:24-34.
6. Petrella JR, Provenzale JM. MR perfusion imaging of the brain: techniques and applications. AJR Am J Roentgenol. 2000;175:207-19.
7. Orsingher L, Piccinini S and Crisi G. Differences in dynamic susceptibility contrast MR perfusion maps generated by different methods implemented in commercial software. J Comput Assist Tomogr 2014;38:647–54.
8. Sugahara TM, Korogi Y, Shigematsu Y, et al. Perfusion-sensitive MRI of cerebral lymphomas: a preliminary report. J Comput Assist Tomogr 1999;23:232–37.
9. Cha S, Lupo JM, Chen MH, et al. Differentiation of glioblastoma multiforme and single brain metastasis by peak height and percentage of signal intensity recovery derived from dynamic susceptibility-weighted contrast-enhanced perfusion MR imaging. AJNR Am J Neuroradiol 2007;28:1078–84.

10. Hartmann M, Heiland S, Harting I, et al. Distinguishing of primary cerebral lymphoma from high-grade glioma with perfusion-weighted magnetic resonance imaging. Neurosci Lett 2003;338:119 –22.
11. Liao W, Liu Y, Wang X, et al. Differentiation of primary central nervous system lymphoma and high-grade glioma with dynamic susceptibility contrast enhanced perfusion magnetic resonance imaging. Acta Radiol 2008;50:2217–25.
12. Bauchet L, Ostrom QT. Epidemiology and Molecular Epidemiology. Neurosurg Clin N Am. 2019;30:1-16.
13. Ostrom Q.T., Bauchet L., Davis F.G., Deltour I., Fisher J.L., Langer C.E., Pekmezci M., Schwartzbaum J.A., Turner M.C., Walsh K.M., et al. The epidemiology of glioma in adults: A “state of the science” review. Neuro Oncol. 2014;16:896–913.
14. Miller KD, Ostrom QT, Kruchko C, Patil N, Tihan T, Cioffi G, Fuchs HE, Waite KA, Jemal A, Siegel RL, Barnholtz-Sloan JS. Brain and other central nervous system tumor statistics, 2021. CA Cancer J Clin. 2021;71:381-406.
15. World Health Organization. Central Nervous System Tumors. WHO Classification of Tumors Online. 5th ed. https://tumourclassification. iarc.who.int/welcome/. Accessed January 16, 2023.
16. Tang YZ, Booth TC, Bhogal P, et al. Imaging of primary central nervous system lymphoma. Clin Radiol 2011;66:768–77.
17. Mansour A, Qandeel M, Abdel-Razeq H, et al. MR imaging features of intracranial primary CNS lymphoma in immune competent patients. Cancer Imaging 2014;14:1–9.
18. Pons-Escoda A, Garcia-Ruiz A, Naval-Baudin P, et al. Presurgical identification of primary central nervous system lymphoma with normalized time-intensity curve: a pilot study of a new method to analyze DSC-PWI. AJNR Am J Neuroradiol 2020;41:1816–24.
19. Haldorsen IS, Espeland A, Larsson E-M. Central nervous system lymphoma: characteristic findings on traditional and advanced imaging. AJNR Am J Neuroradiol 2011;32:984–92.

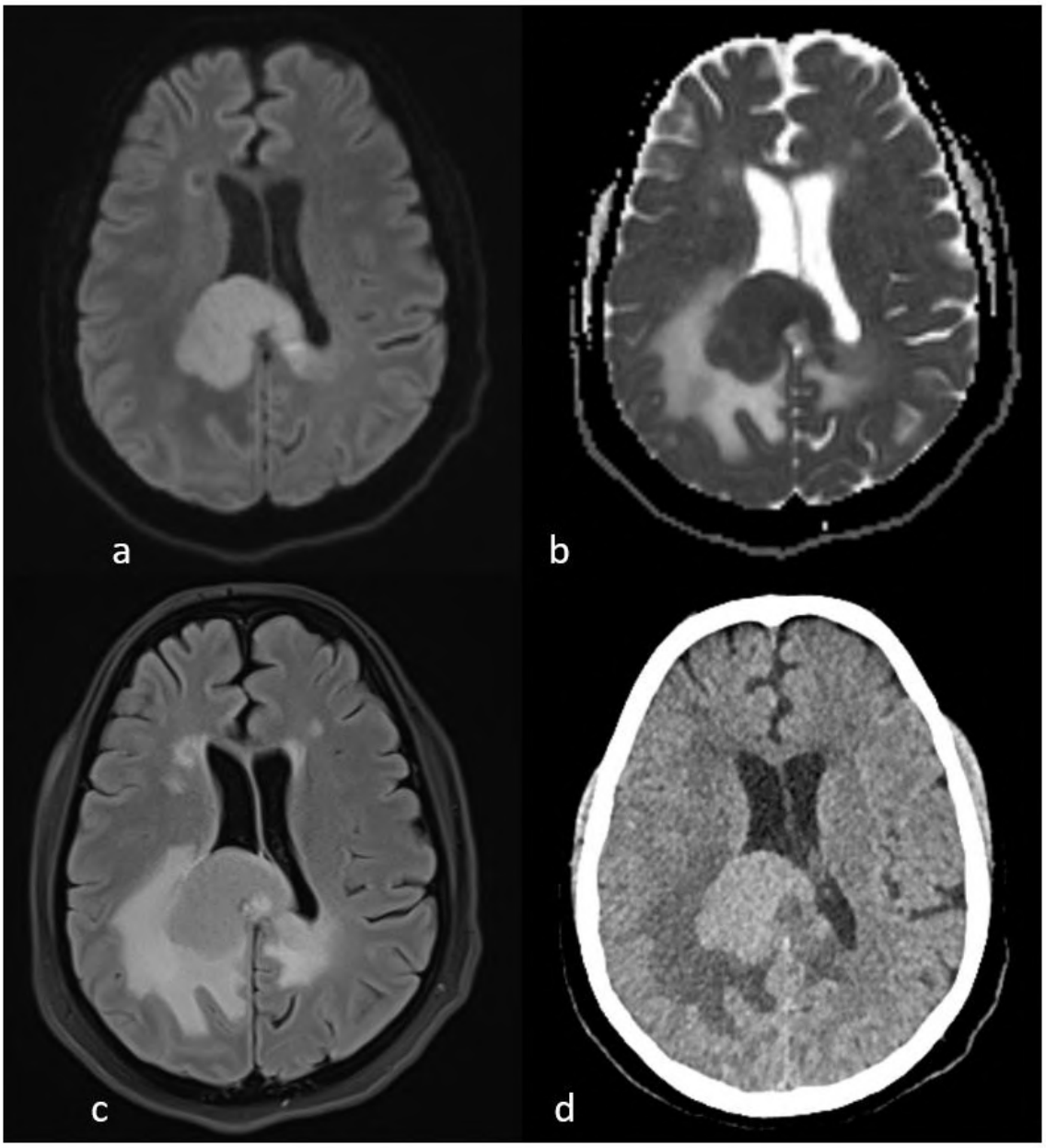
20. Velasco R, Mercadal S, Vidal N, et al; GELTAMO and GENOSEN Group. Diagnostic delay and outcome in immunocompetent patients with primary central nervous system lymphoma in Spain: a multicentric study. J Neurooncol 2020;148:545–54.
21. Sakata A, Okada T, Yamamoto A, Kanagaki M, Fushimi Y, Dodo T, Arakawa Y, Takahashi JC, Miyamoto S, Togashi K. Primary central nervous system lymphoma: is absence of intratumoral hemorrhage a characteristic finding on MRI? Radiol Oncol. 2015;49:128-34.
22. Pope WB. Brain metastases: neuroimaging. Handb Clin Neurol 2018;149:89–112.
23. Achrol AS, Rennert RC, Anders C, Soffietti R, Ahluwalia MS, Nayak L, et al. Brain metastases. Nat Rev Dis Primers 2019;5: 5.
24. Aronen HJ, Gazit IE, Louis DN, et al. Cerebral blood volume maps of gliomas: comparison with tumor grade and histologic findings. Radiology 1994; 191:41–51.
25. Rizzo L, Crasto SG, Moruno PG, Cassoni P, Rudà R, Boccaletti R, Brosio M, De Lucchi R, Fava C. Role of diffusion- and perfusion-weighted MR imaging for brain tumour characterisation. Radiol Med. 2009 Jun;114(4):645-59.
26. Jarnum H, Steffensen EG, Knutsson L, et al. Perfusion MRI of brain tumours: a comparative study of pseudo-continuous arterial spin labeling and dynamic susceptibility contrast imaging, Neuroradiology 2010; 52(4): 307–317.
27. Lee IH, Kim ST, Kim HJ, Kim KH, Jeon P, Byun HS. Analysis of perfusion weighted image of CNS lymphoma. Eur J Radiol. 2010 Oct;76(1):48-51.
28. Toh CH, Wei KC, Chang CN, Ng SH, Wong HF. Differentiation of primary central nervous system lymphomas and glioblastomas: comparisons of diagnostic performance of dynamic susceptibility contrast-enhanced perfusion MR imaging without and with contrast-leakage correction. AJNR Am J Neuroradiol. 2013l;34:1145-9.
29. Xing Z, Roger X, You J, Li, Liu Y, Cao D. Differentiation of primary central nervous system lymphomas from high-grade gliomas by rCBV and percentage of signal intensity recovery derived from

dynamic susceptibility-weighted contrast-enhanced perfusion MR imaging. Clin Neuroradiol 2014; 24:329-36.

30. Goyal, P., Kumar, Y., Gupta, N., Malhotra, A., Gupta, S., Gupta, S., Mangla, M., & Mangla, R. (2017). Usefulness of enhancement-perfusion mismatch in differentiation of CNS lymphomas from other enhancing malignant tumors of the brain. Quantitative Imaging In Medicine And Surgery, 7(5), 511-519.
31. Soni N, Dhanota DPS, Kumar S, Jaiswal AK, Srivastava AK. Perfusion MR imaging of enhancing brain tumors: Comparison of arterial spin labeling technique with dynamic susceptibility contrast technique. Neurol India. 2017;65:1046-52.
32. Lee MD, Baird GL, Bell LC, Quarles CC, Boxerman JL. Utility of Percentage Signal Recovery and Baseline Signal in DSC-MRI Optimized for Relative CBV Measurement for Differentiating Glioblastoma, Lymphoma, Metastasis, and Meningioma. AJNR Am J Neuroradiol. 2019;40:1445-50.
33. Surendra K L, Patwari S, Agrawal S, Chadaga H, Nagadi A. Percentage signal intensity recovery: A step ahead of rCBV in DSC MR perfusion imaging for the differentiation of common neoplasms of brain. Indian J Cancer. 2020;57:36-43.
34. Cindil E, Sendur HN, Cerit MN, Dag N, Erdogan N, Celebi FE, Oner Y, Tali T. Validation of combined use of DWI and percentage signal recovery-optimized protocol of DSC-MRI in differentiation of high-grade glioma, metastasis, and lymphoma. Neuroradiology. 2021 ;63:331-42.
35. Chakravorty A, Steel TR, Chaganti JR. Accuracy of percentage of signal intensity recovery and relative cerebral blood volume derived from dynamic susceptibility-weighted, contrast-enhanced MRI in the preoperative diagnosis of cerebral tumors. Neuroradiol J 2015; 28:574-83.
36. Barajas RF, Cha S. Benefits of dynamic susceptibility-weighted contrast-enhanced perfusion MRI for glioma diagnosis and therapy. CNS Oncol 2014;3:407-19.

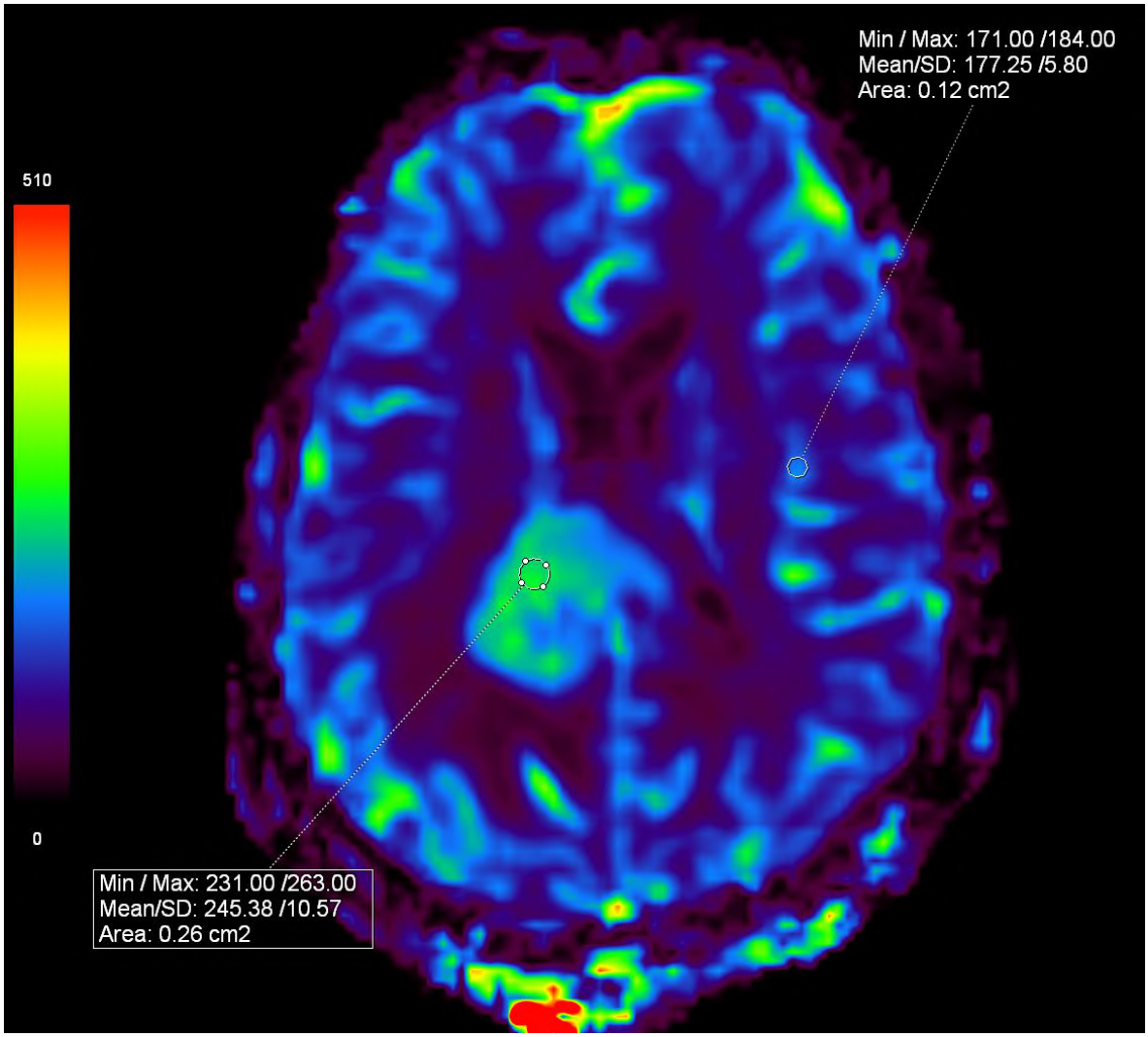
37. Chinchure S, Thomas B, Wangju S, Jolappara M, Kesavadas C, Kapilamoorthy TR, et al. Mean intensity curve on dynamic contrast-enhanced susceptibility-weighted perfusion MR imaging--review of a new parameter to differentiate intracranial tumors. J Neuroradiol 2011;38:199-206.
38. Wetzel SG, Cha S, Johnson G, Lee P, Law M, KasowDL, et al. Relative cerebral blood volume measurements in intracranial mass lesions: Interobserver and intraobserver reproducibility study. Radiology 2002;224:797-803.
39. Calli C, Kitis O, Yunten N, Yurtseven T, Islekel S, Akalin T, et al. Perfusion and diffusion MR imaging in enhancing malignant cerebral tumors. Eur J Radiol 2006;58:394-403.
40. Haldorsen IS, Espeland A, Larsen JL, et al. Diagnostic delay in primary central nervous system lymphoma. Acta Oncol 2005;44:728 –34.
41. Roman-Goldstein SM, Goldman DL, Howieson J, et al. MR of primary CNS lymphoma in immunologically normal patients. AJNR Am J Neuroradiol 1992;13:1207–13.
42. Kuker W, Nagele T, Korfel A, et al. Primary central nervous system lymphomas (PCNSL): MRI features at presentation in 100 patients. J Neurooncol 2005;72:169 –77.
43. Buhring U, Herrlinger U, Krings T, et al. MRI features of primary central nervous system lymphomas at presentation. Neurology 2001; 57:393.
44. Porter B, Giannini C, Kaufmann T, et al. Primary central nervous system lymphoma can be histologically diagnosed after previously corticosteroid use: a pilot study to determine whether corticosteroids prevent the diagnosis of primary central nervous system lymphoma. Ann Neurol 2008;63:662–67.
45. Jhaveri MD. Chapter 173: diffuse large B-cell lymphoma. In: Jhaveri MD, Osborn AG, Salzman KL. Diagnostic Imaging: Brain. 4th ed. Elsevier; 2020:602–06.

46. LupoJM, ChaS, ChangSM, NelsonSJ. Dynamic susceptibility-weighted perfusion imaging of high-grade gliomas: Characterization of spatial heterogeneity. AJNR Am J Neuroradiol 2005;26:1446-54.
47. Law M, Cha S, Knopp EA, Johnson G, Arnett J, Litt AW, et al. High-grade gliomas and solitary metastases: Differentiation by using perfusion and proton spectroscopic MR imaging. Radiology 2002; 222:715-21.
48. Schiff D. Single brain metastasis. Curr Treat Options Neurol 2001; 3:89-99.
49. Fox B.D., Cheung V.J., Patel A.J., Suki D., Rao G. Epidemiology of Metastatic Brain Tumors. Neurosurg. Clin. N. Am. 2011;22:1–6.
50. Patchell R.A., Tibbs P.A., Walsh J.W., Dempsey R.J., Maruyama Y., Kryscio R.J., Markesbery W.R., Macdonald J.S., Young B. A randomized trial of surgery in the treatment of single metastases to the brain. N. Engl. J. Med. 1990;322:494–500.
51. Gavrilovic I.T., Posner J.B. Brain metastases: Epidemiology and pathophysiology. Neurooncology. 2005;75:5–14.
52. Lee E.J., Ahn K.J., Lee E.K., Lee Y.S., Kim D.B. Potential role of advanced MRI techniques for the peritumoral region in differentiating glioblastoma multiforme and solitary metastatic lesions. Clin. Radiol. 2013;68:689–97.

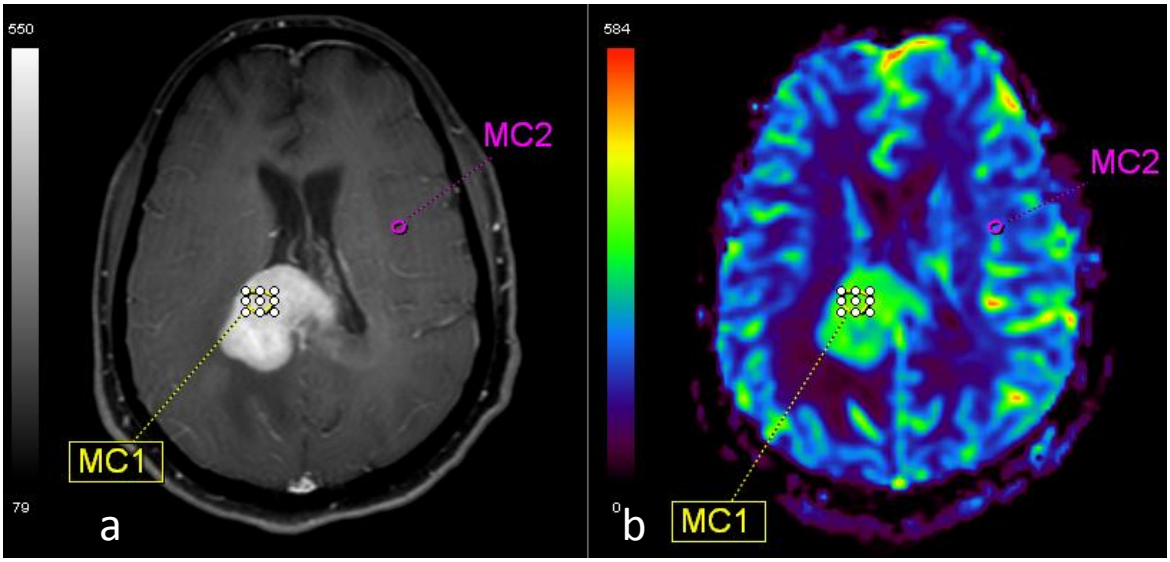


Picture 1: Case 1: 48-year-old female with histopathologically proven diffuse large B-cell lymphoma. A lobulated lesion showing intermediate signal intensity on FLAIR images is seen involving the body and splenium of corpus callosum, and pericallosal cortex with significant diffusion restriction. The lesion is hyperdense on NCCT.

a: DWI, b: ADC, c: FLAIR, and d: NCCT

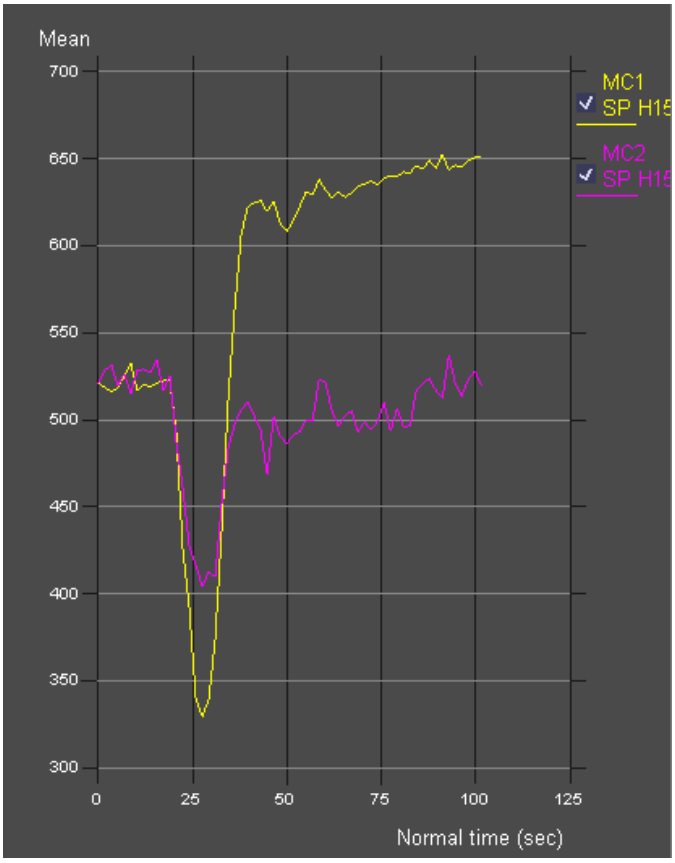


Picture 2: Case 1: CBF perfusion map shows rCBF value of 1.38 in the lesion.

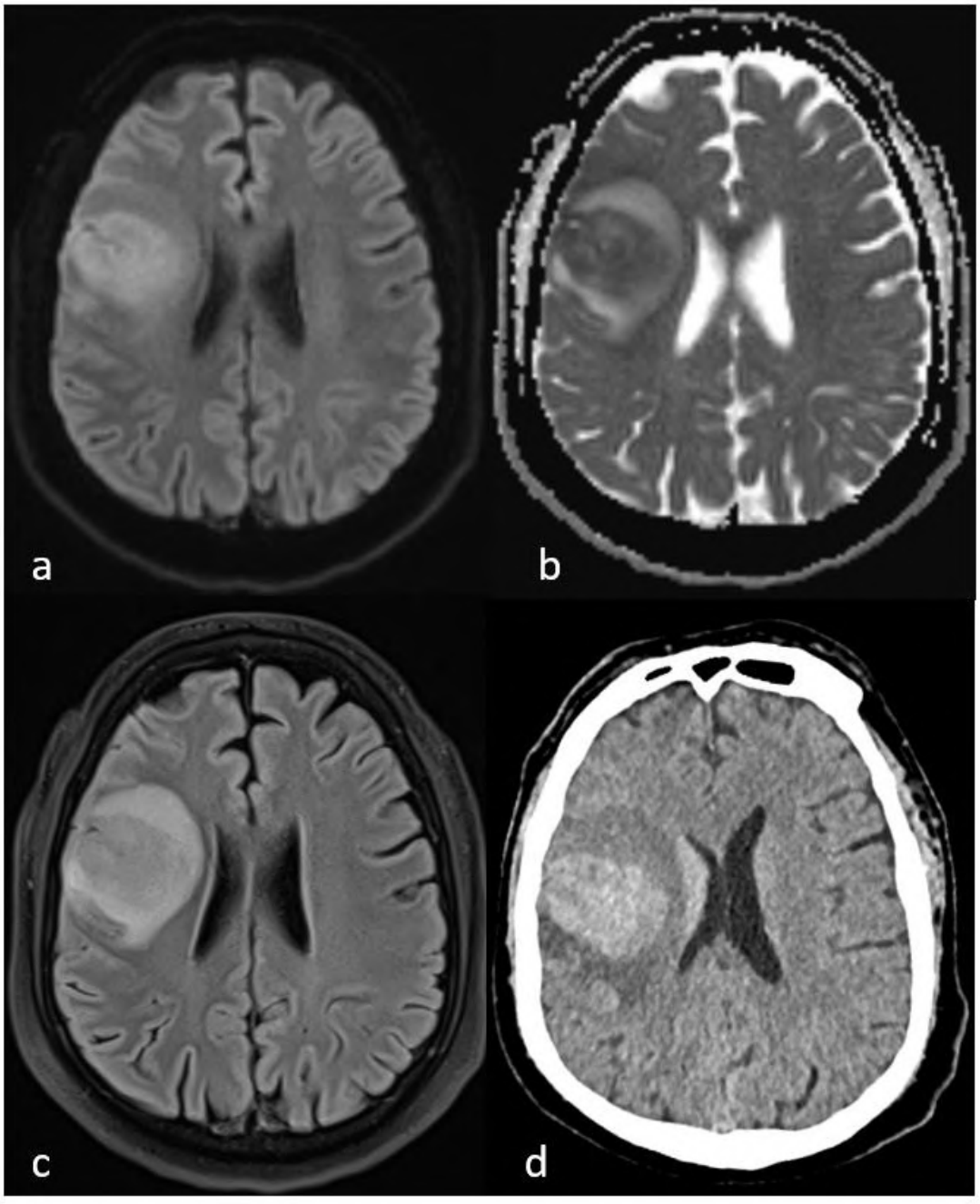


Picture 3: Case 1: The lesion shows intense homogeneous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

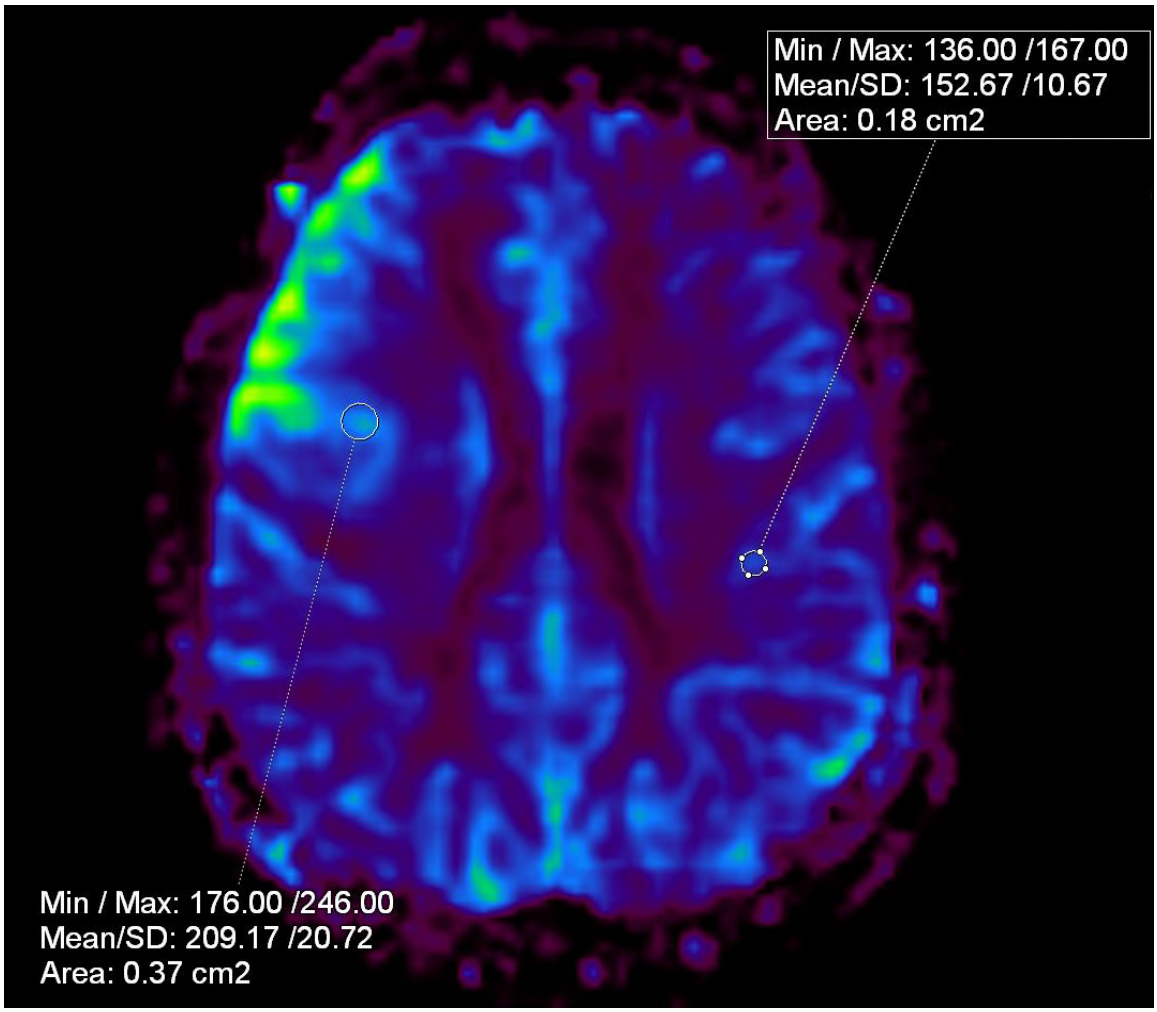


Picture 4: Case 1: Percentage signal recovery of the lesion is 150% and rPSR is 1.7.

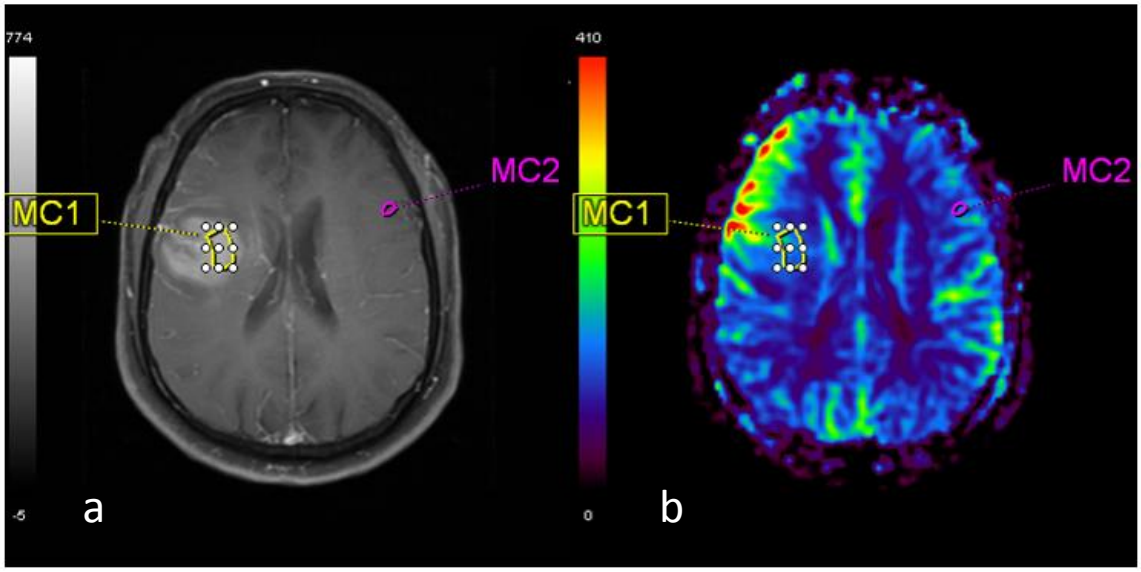


Picture 5: Case 2: 55-year-old male with histopathologically proven diffuse large B-cell lymphoma. An ill-defined area showing intermediate signal intensity on FLAIR images is seen involving cortex and subcortical white matter inright frontal lobe with significant diffusion restriction and moderate white matter edema. The lesion is hyperdense on NCCT.

a: DWI, b: ADC, c: FLAIR, and d: NCCT

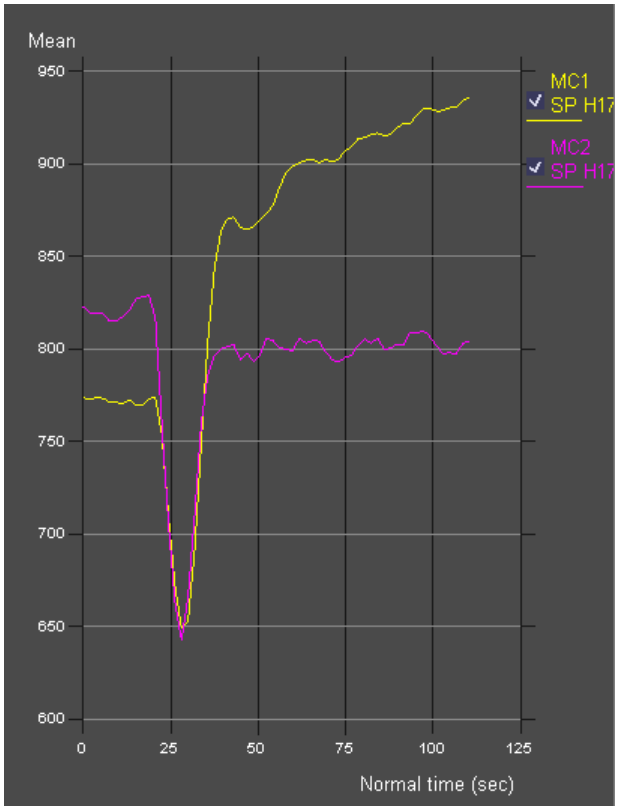


Picture 6: Case 2: CBF perfusion map shows rCBF value of1.37 in the lesion.

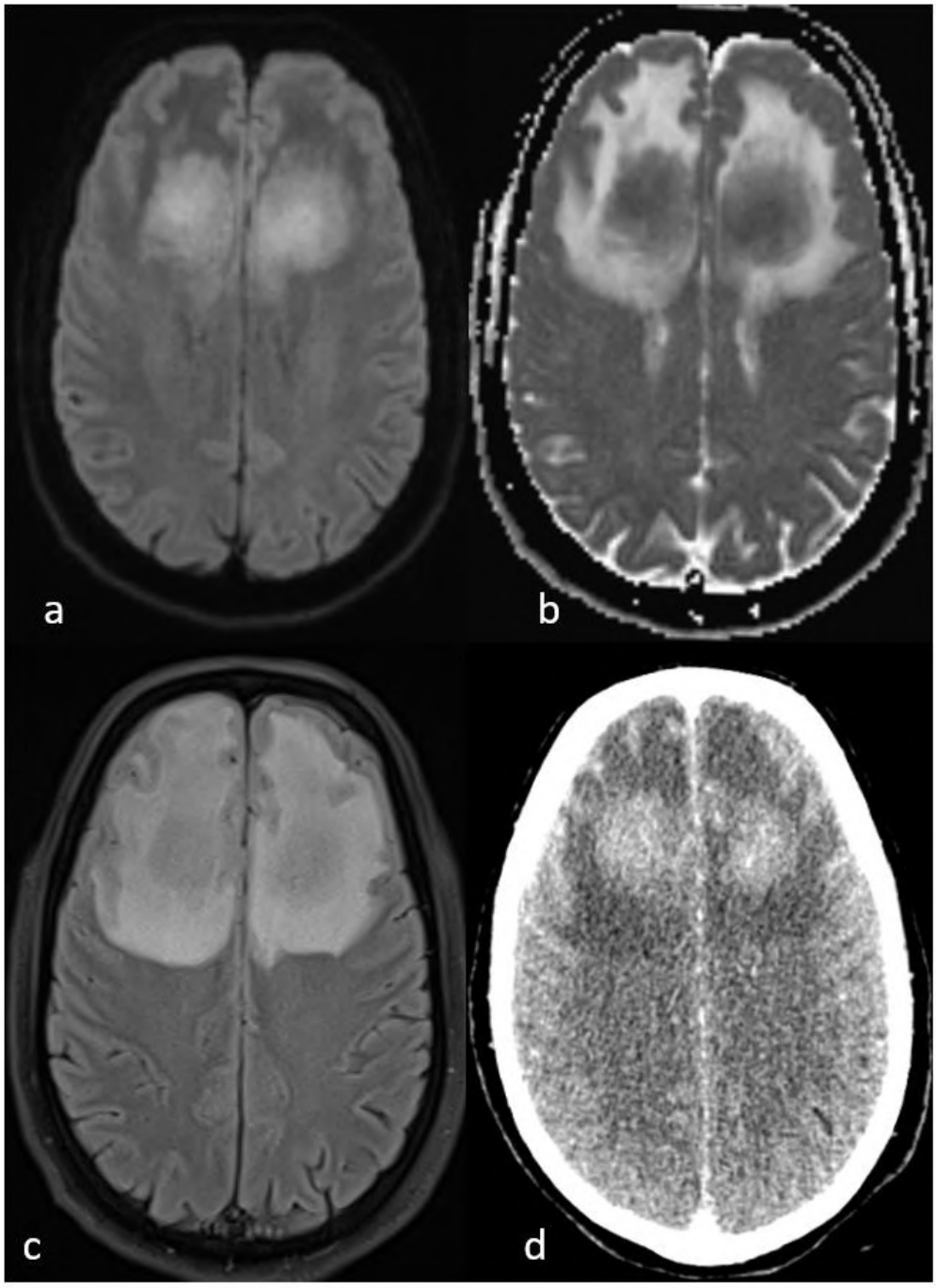


Picture 7: Case 2: The lesion shows nearly homogeneous solid post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

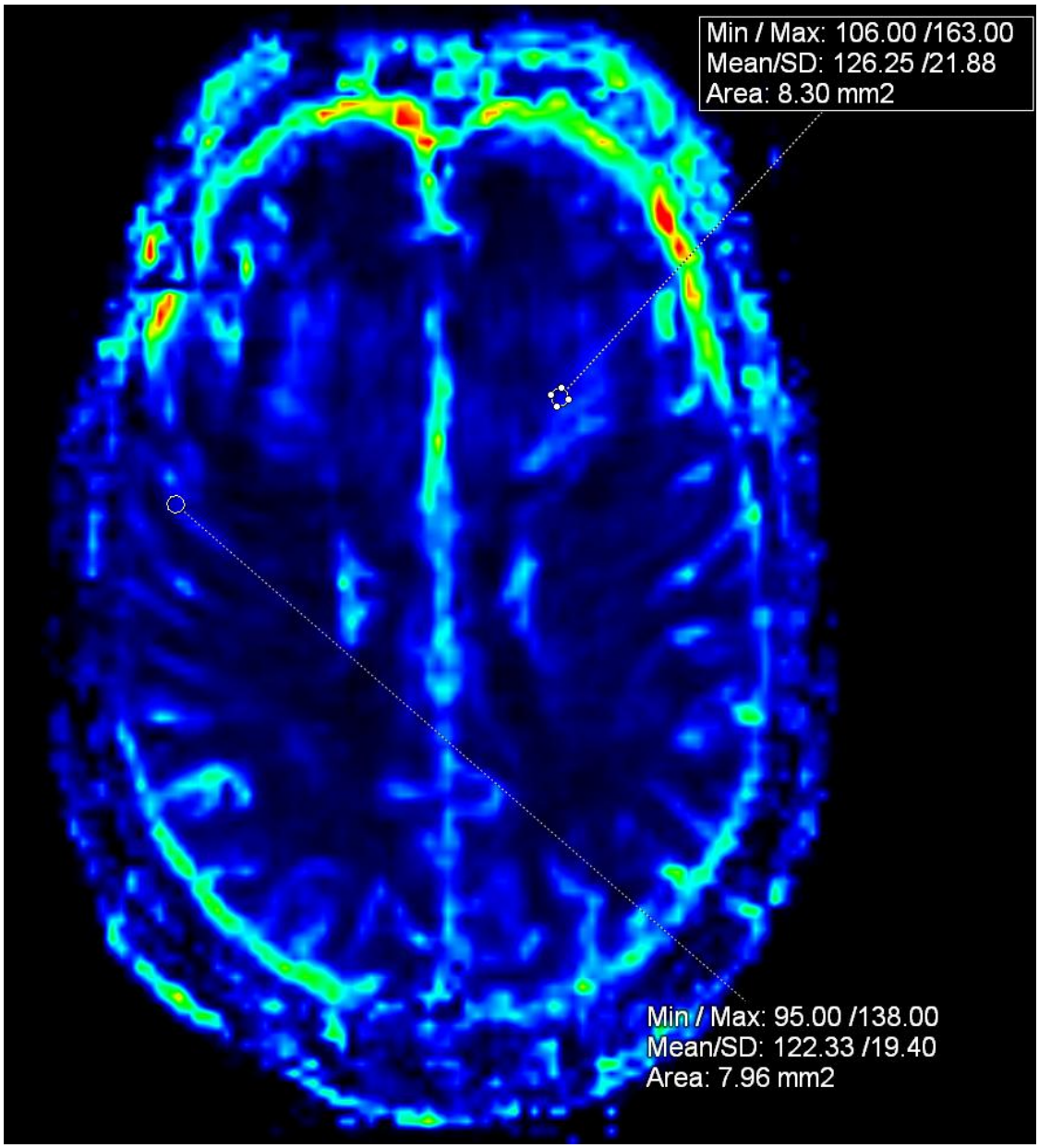


Picture 8: Case 2: Percentage signal recovery of the lesion is 139% and rPSR is 1.5.

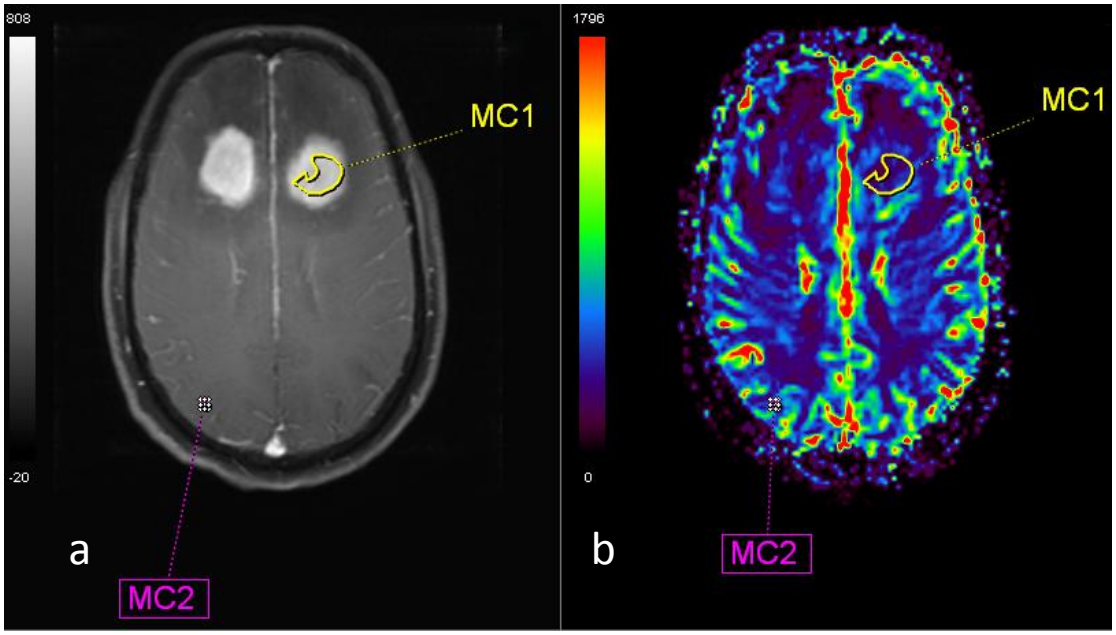


Picture 9: Case 3: 67-year-old female with histopathologically proven diffuse large B-cell lymphoma. Two well-defined lesions showing intermediate signal intensity on FLAIR images are seen involving bilateral frontal lobes with diffusion restriction and extensive white matter edema. The lesions are hyperdense on NCCT.

a: DWI, b: ADC, c: FLAIR, and d: NCCT.

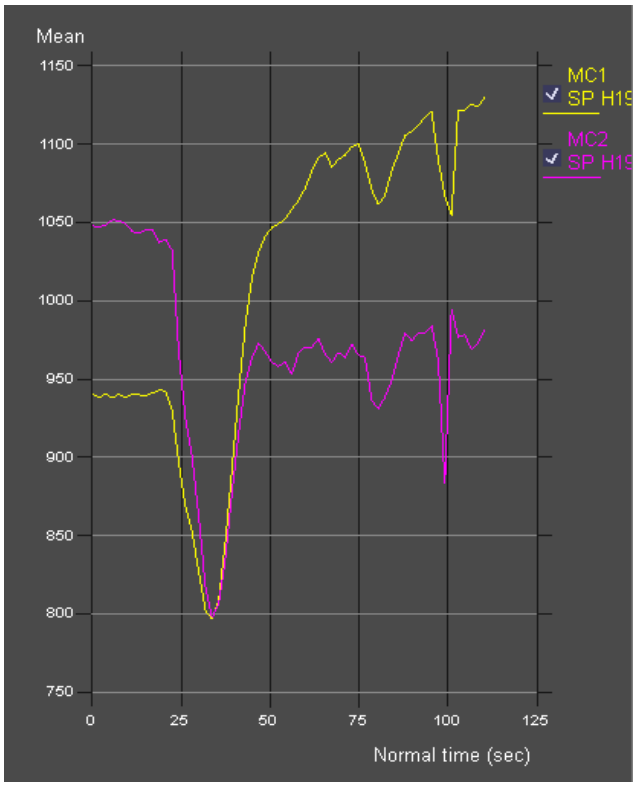


Picture 10: Case 3: CBF perfusion map shows rCBF value of 1.03 in the lesion.

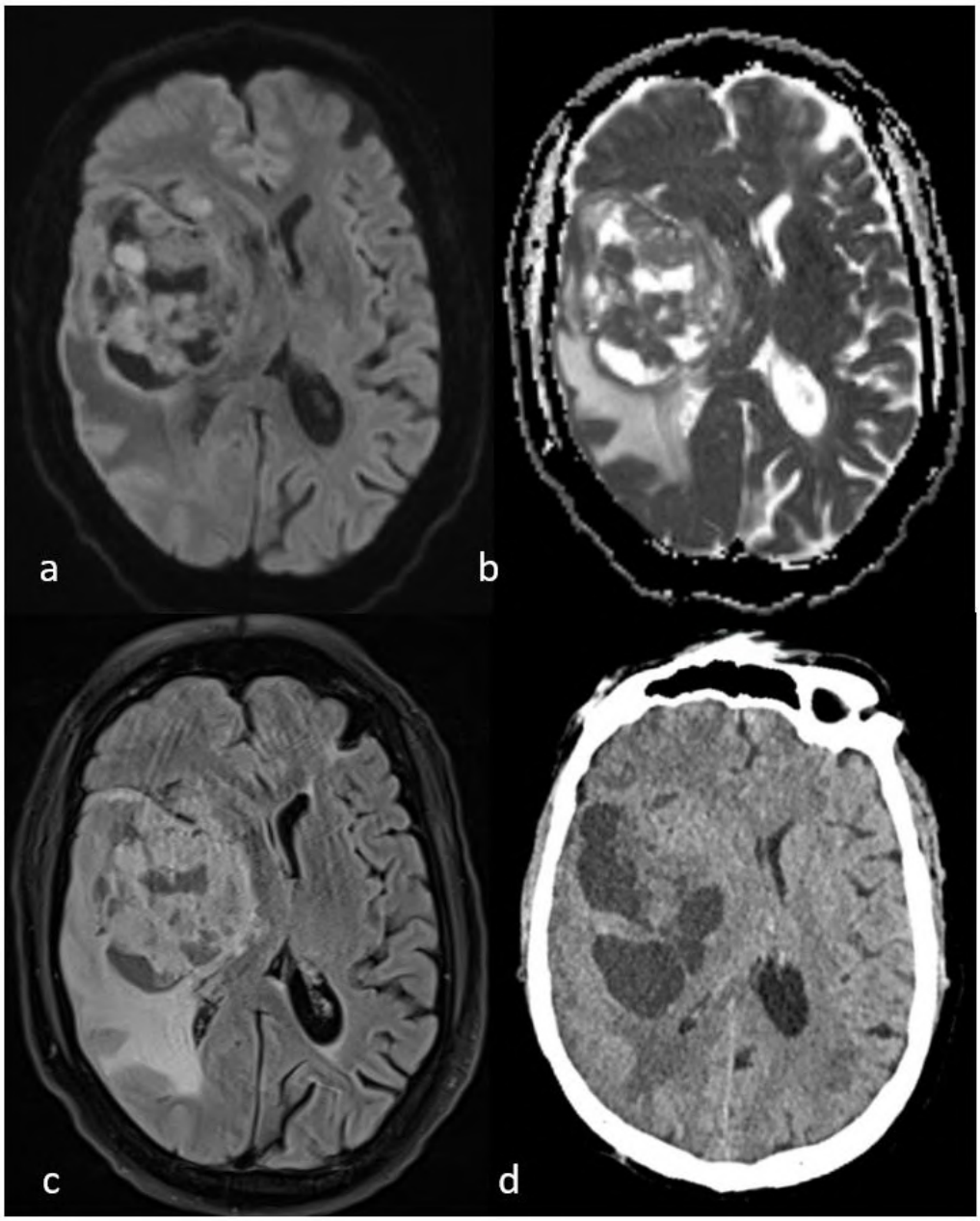


Picture 11: Case 3: The lesion shows nearly homogeneous solid post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

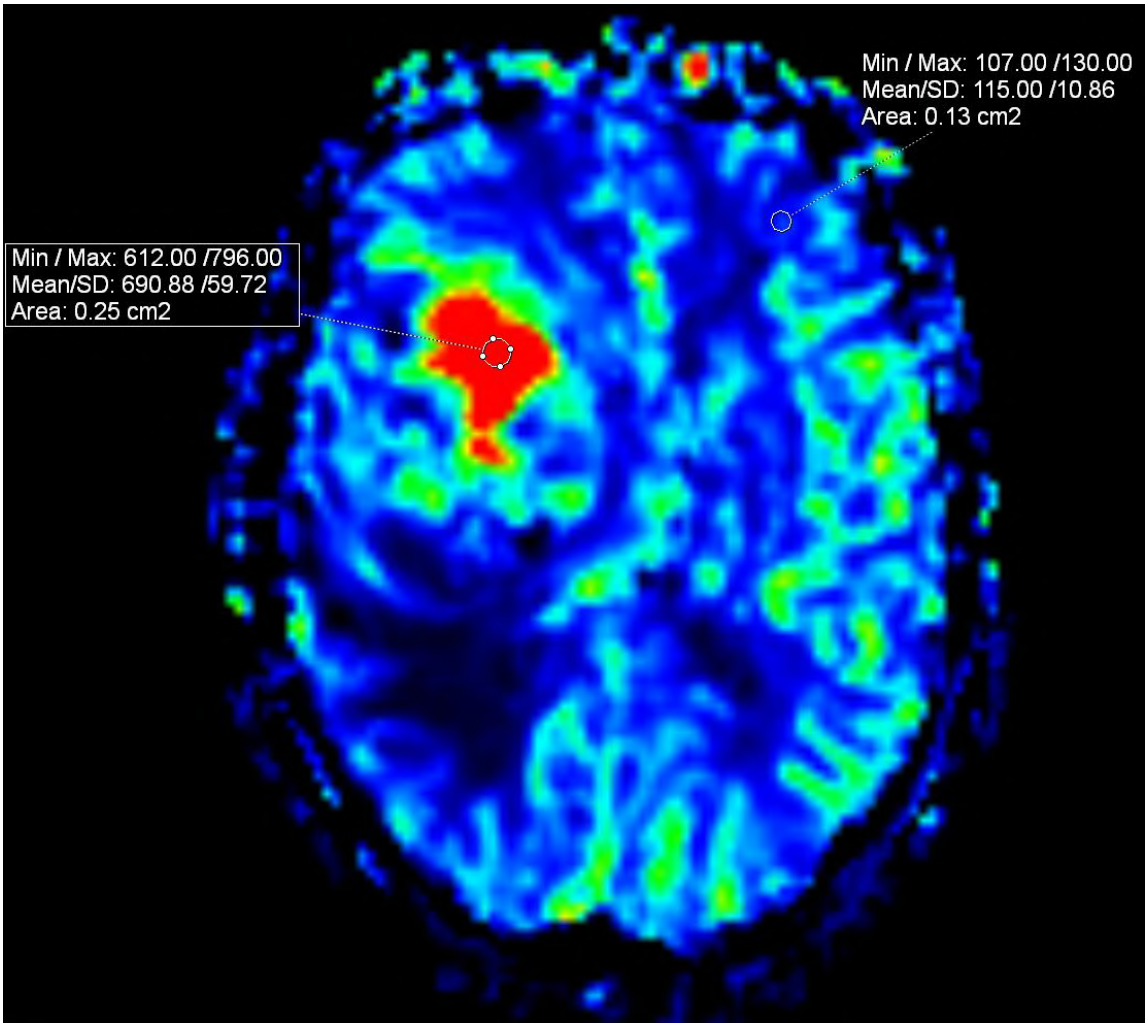


Picture 12: Case 3: Percentage signal recovery of the lesion is 158% and rPSR is 1.8.

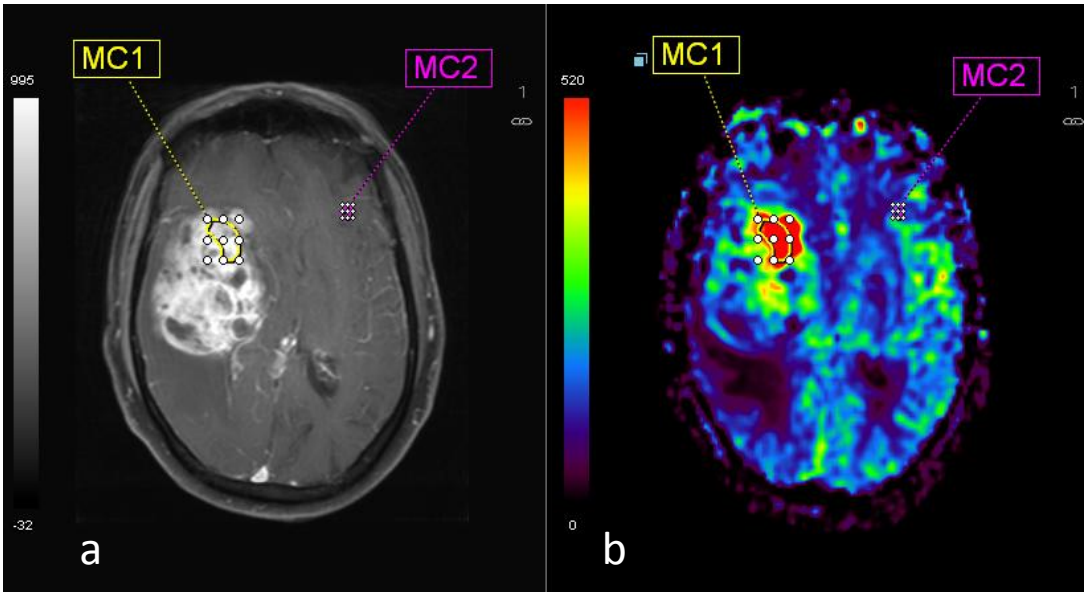


Picture 13: Case 4: 57-year-old female with histopathologically proven high-grade glioma. A lobulated intermediate signal intensity lesion showing areas of cystic degeneration on FLAIR images is seen involving subcortical and deep white matter of right temporoparietal lobe with patchy diffusion restriction. The lesion is heterogeneously hypodense on NCCT.

a: DWI, b: ADC, c: FLAIR, and d: NCCT.

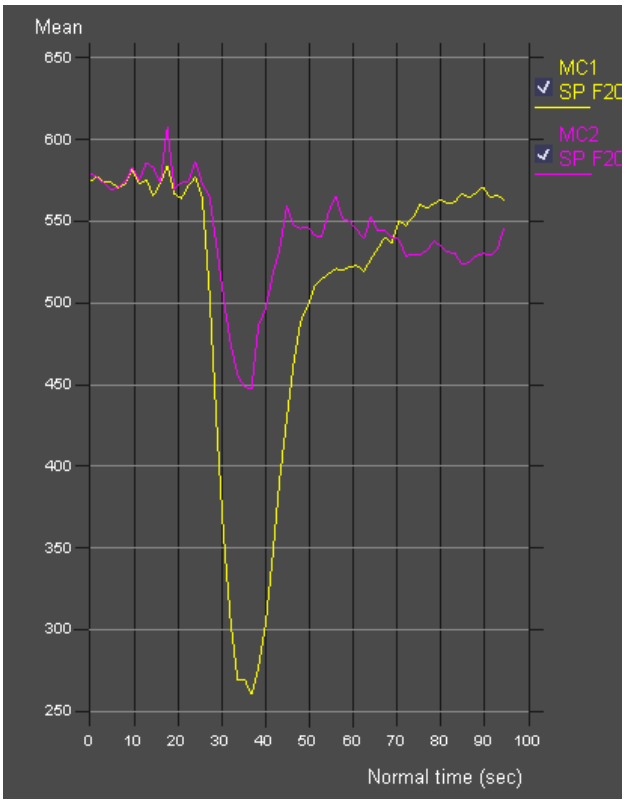


Picture 14: Case 4: CBF perfusion map shows rCBF value of 6 in the lesion.

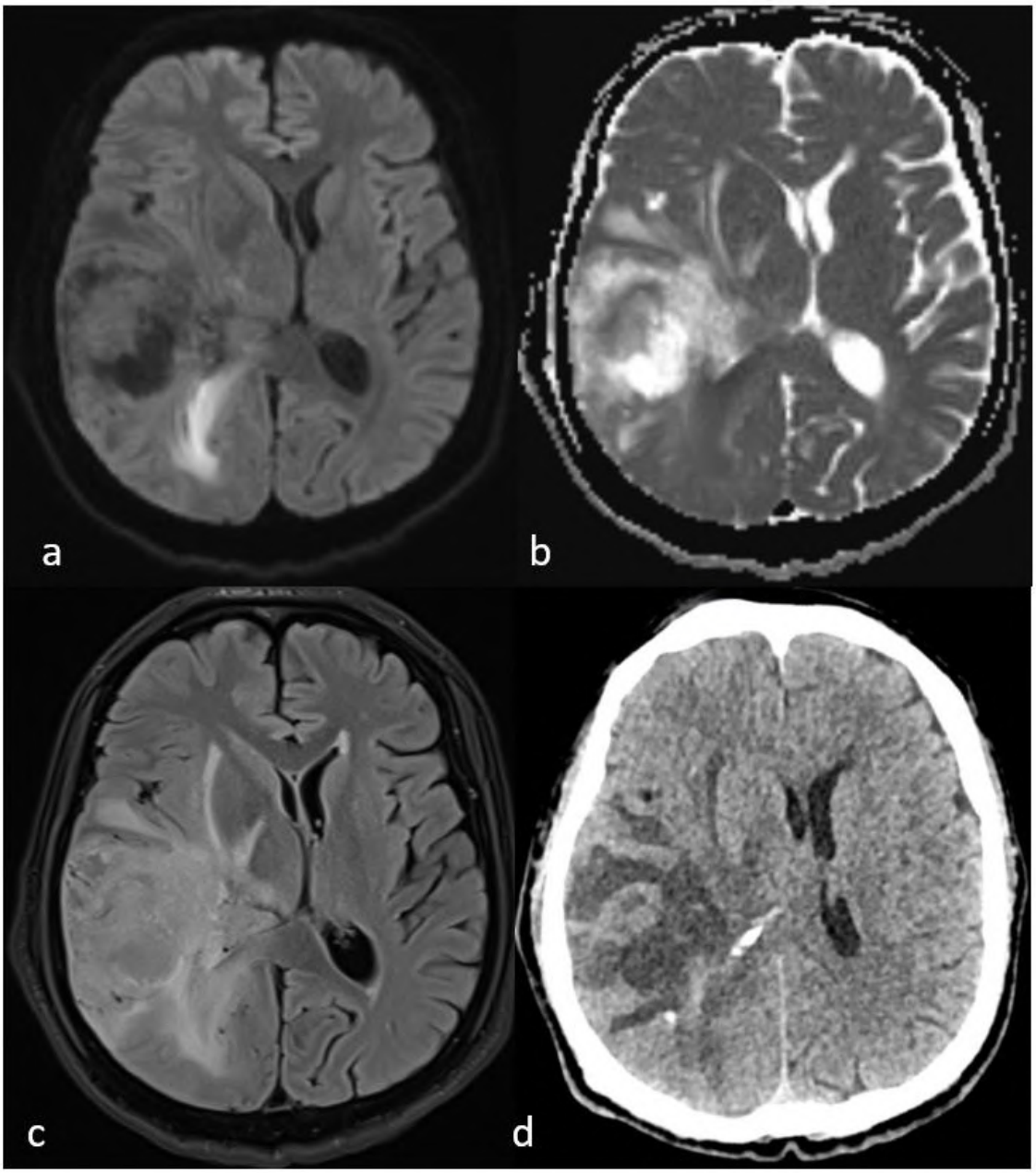


Picture 15: Case 4: Lesion shows heterogeneous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

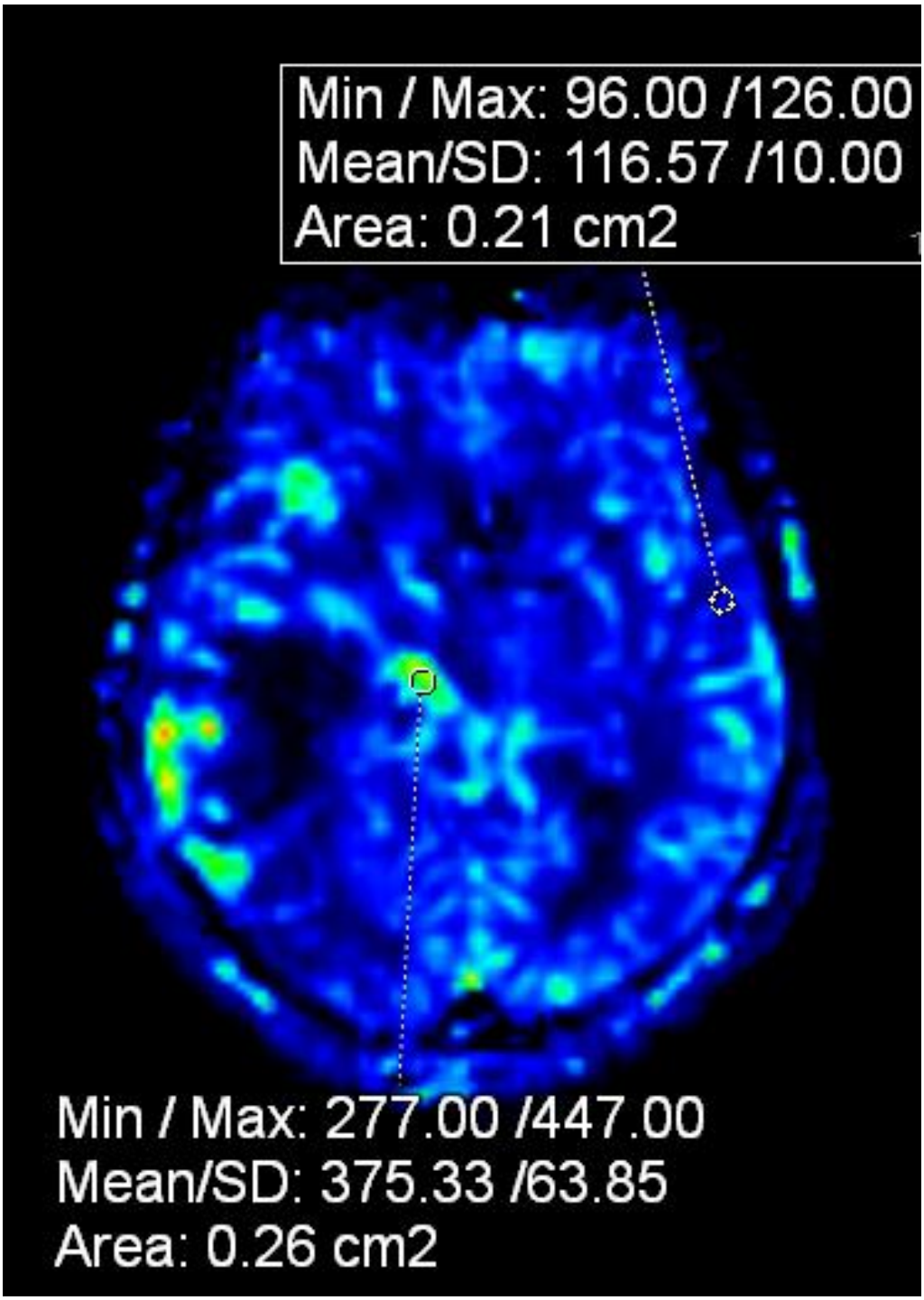


Picture 16: Case 4: Percentage signal recovery of the lesion is 78% and rPSR is 0.81.

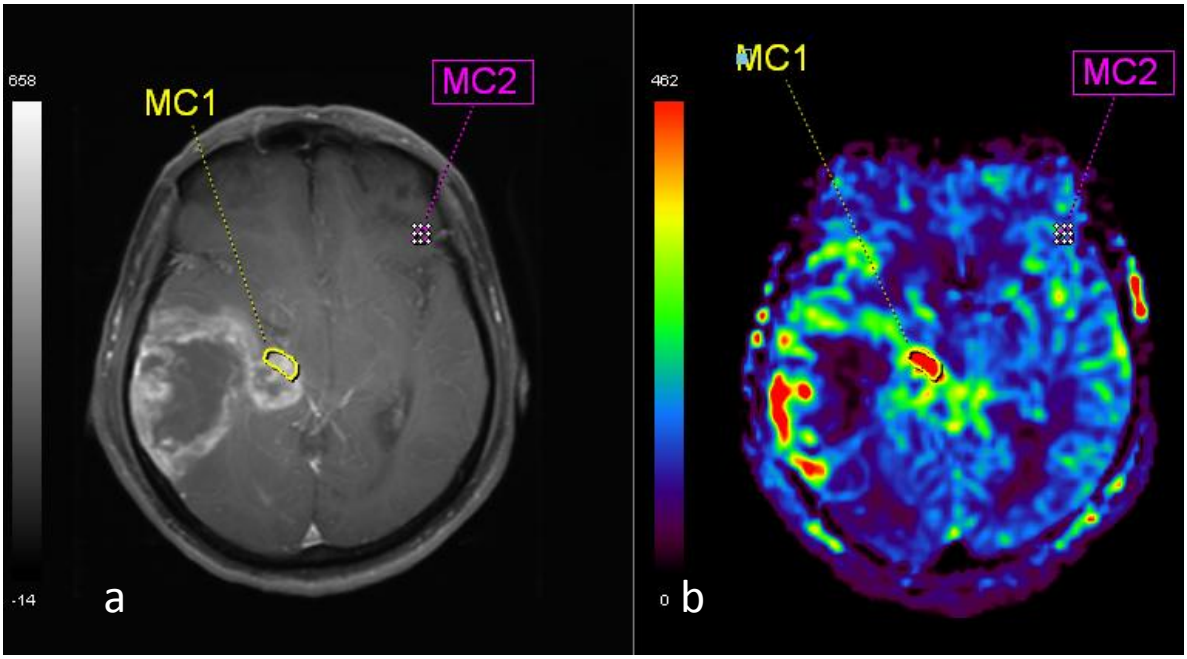


Picture 17: Case 5: 62-year-old male with histopathologically proven high-grade glioma. An area of altered signal intensity appearing heterogeneously hyperintense on FLAIR images is seen involving cortex, subcortical, and deep white matter of right temporoparietal lobe with no significant diffusion restriction. The lesion is heterogeneously hypodense on NCCT.

a: DWI, b: ADC, c: FLAIR, and d: NCCT

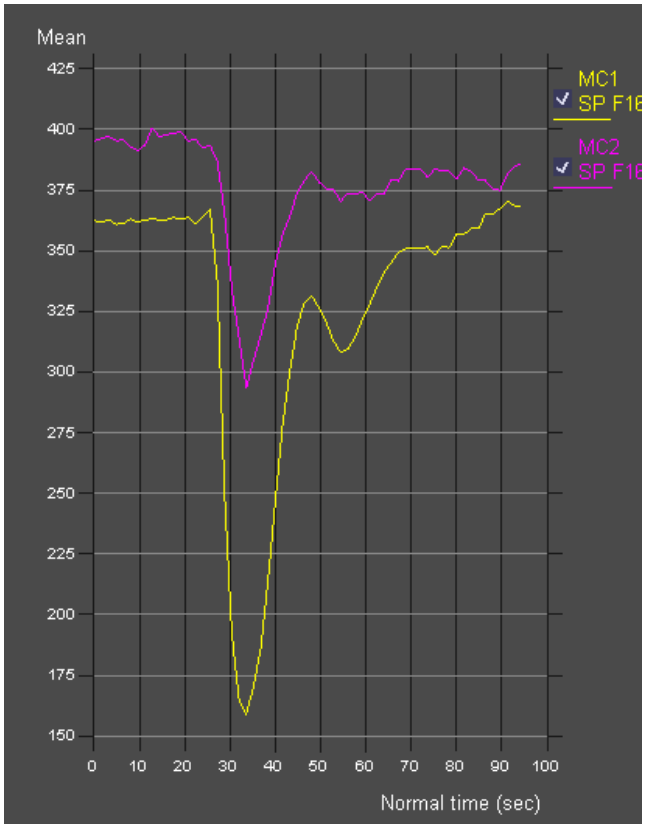


Picture 18: Case 5: CBF perfusion map shows rCBF value of 3.2 in the lesion.

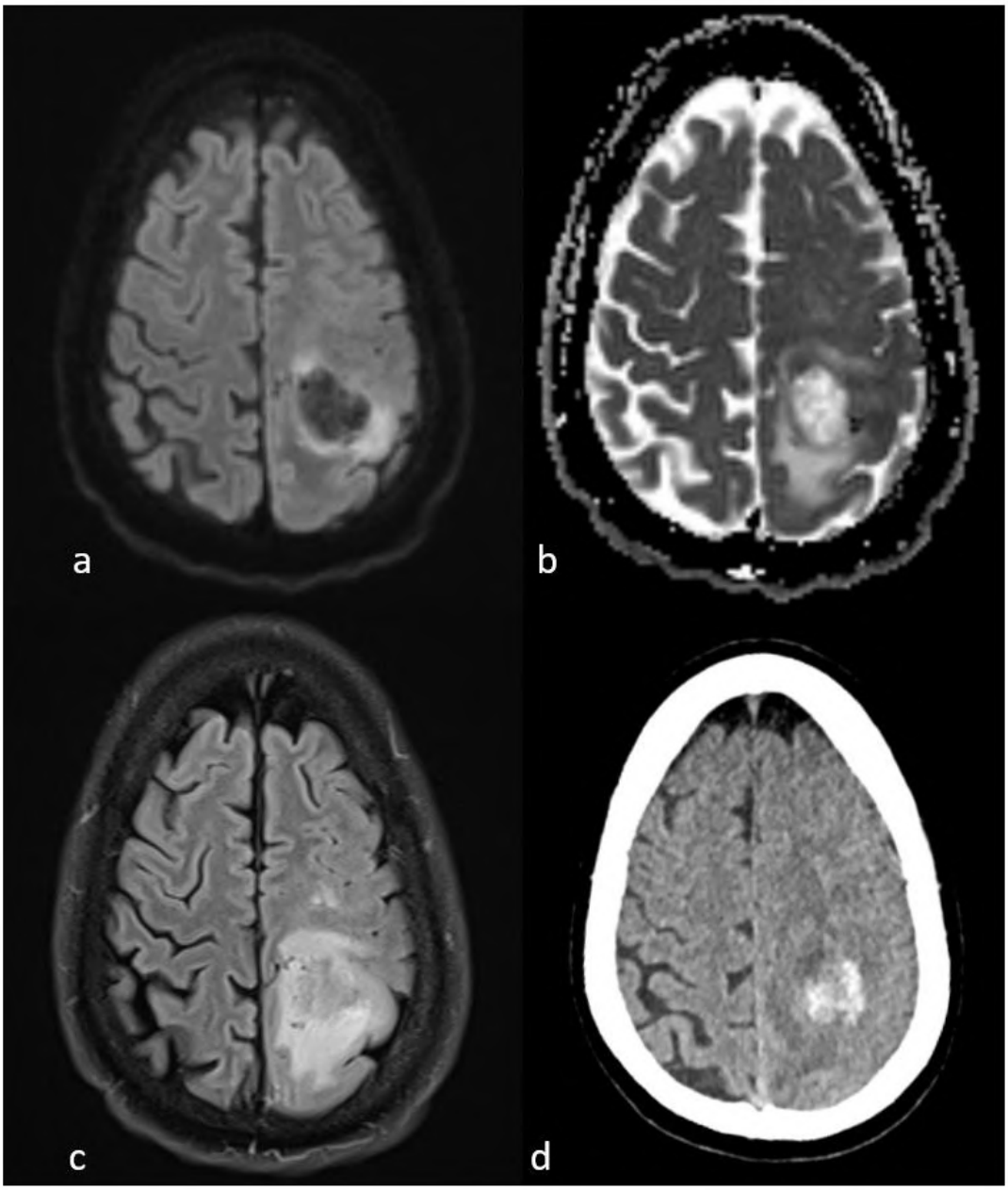


Picture 19: Case 5: Lesion shows thick peripheral post-contrast enhancement on T1WI.Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

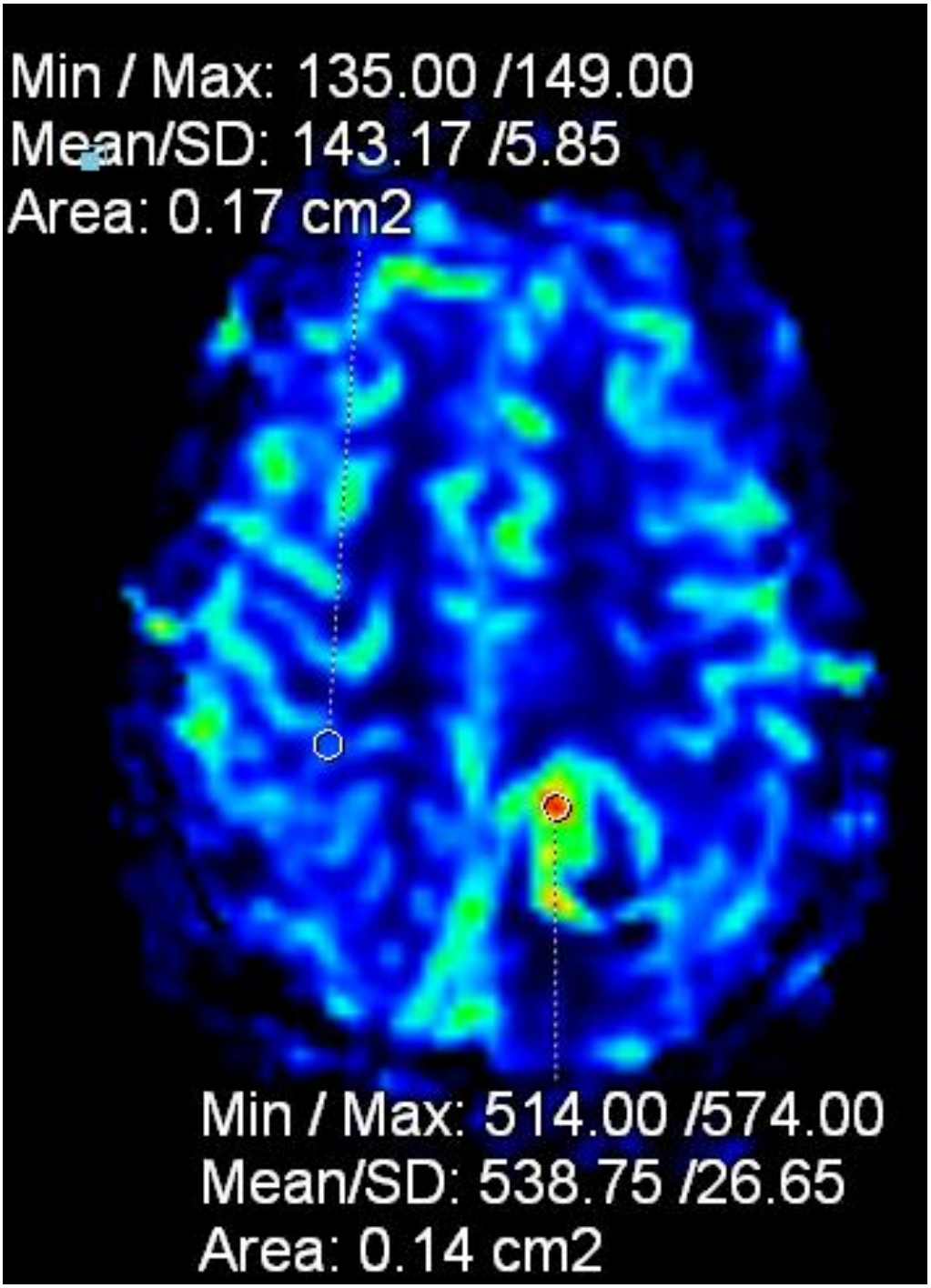


Picture 20: Case 5: Percentage signal recovery of the lesion is 80% and rPSR is 0.9.

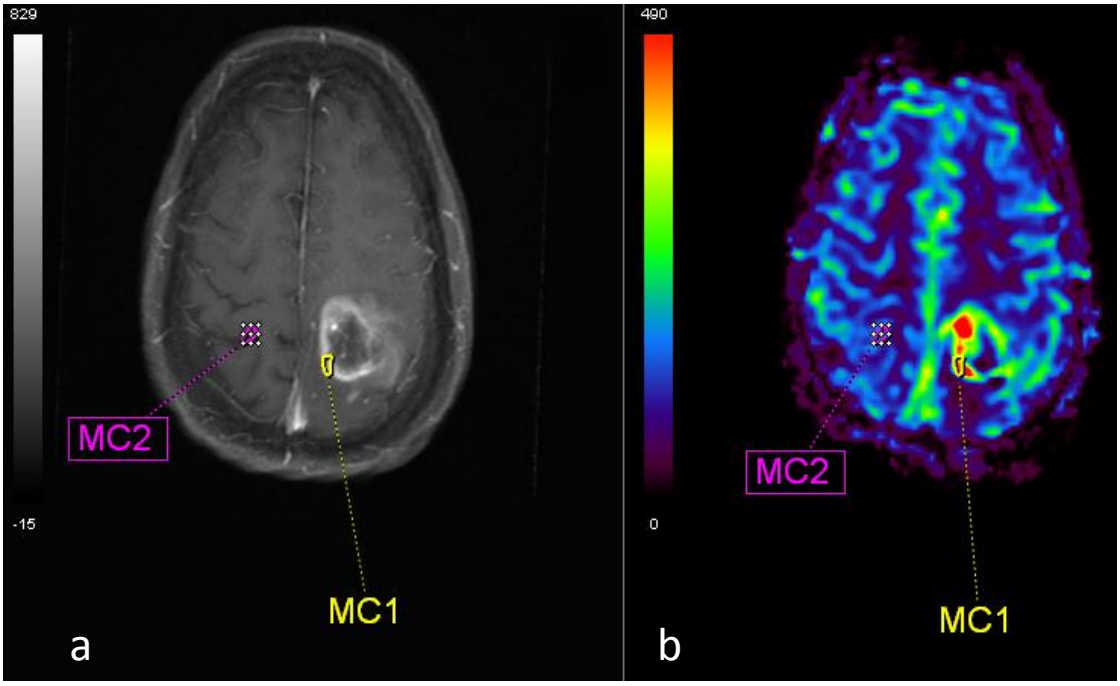


Picture 21: Case 6: 55-year-old male with histopathologically proven high-grade glioma. A lobulated lesion with intermediate signal intensity is seen on FLAIR images involving the white matter in left parietal lobe with peripheral diffusion restriction on DWI/ADC images. The lesion is heterogeneously hyperdense on NCCT due to hemorrhage.

a: DWI, b: ADC, c: FLAIR, and d: NCCT.

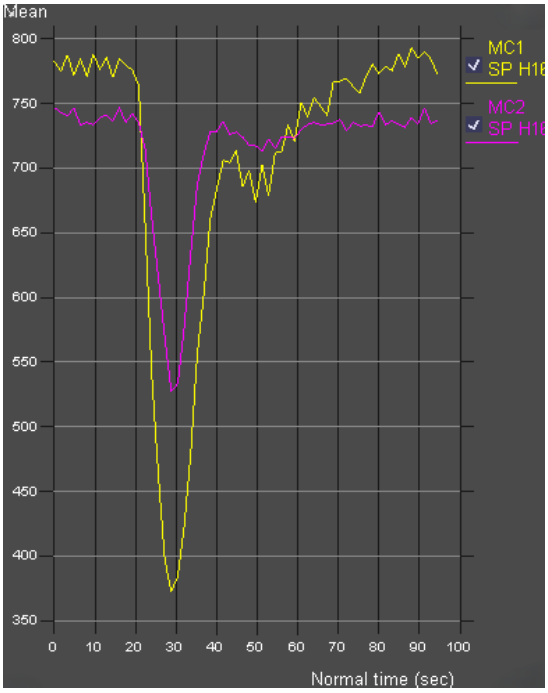


Picture 22: Case 6: CBF perfusion map shows rCBF value of 3.7 in the lesion.

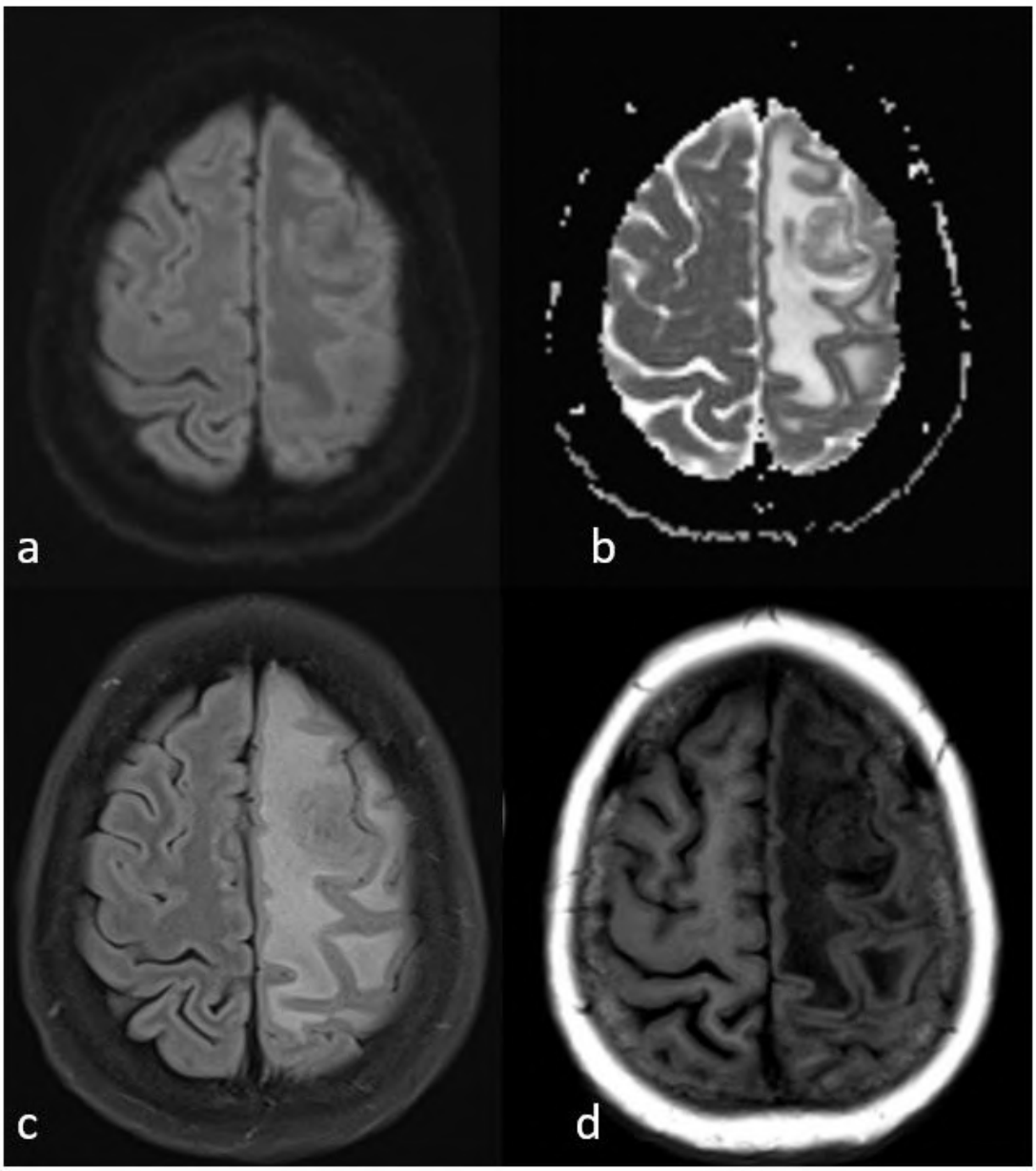


Picture 23: Case 6: Lesion shows thick peripheral post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

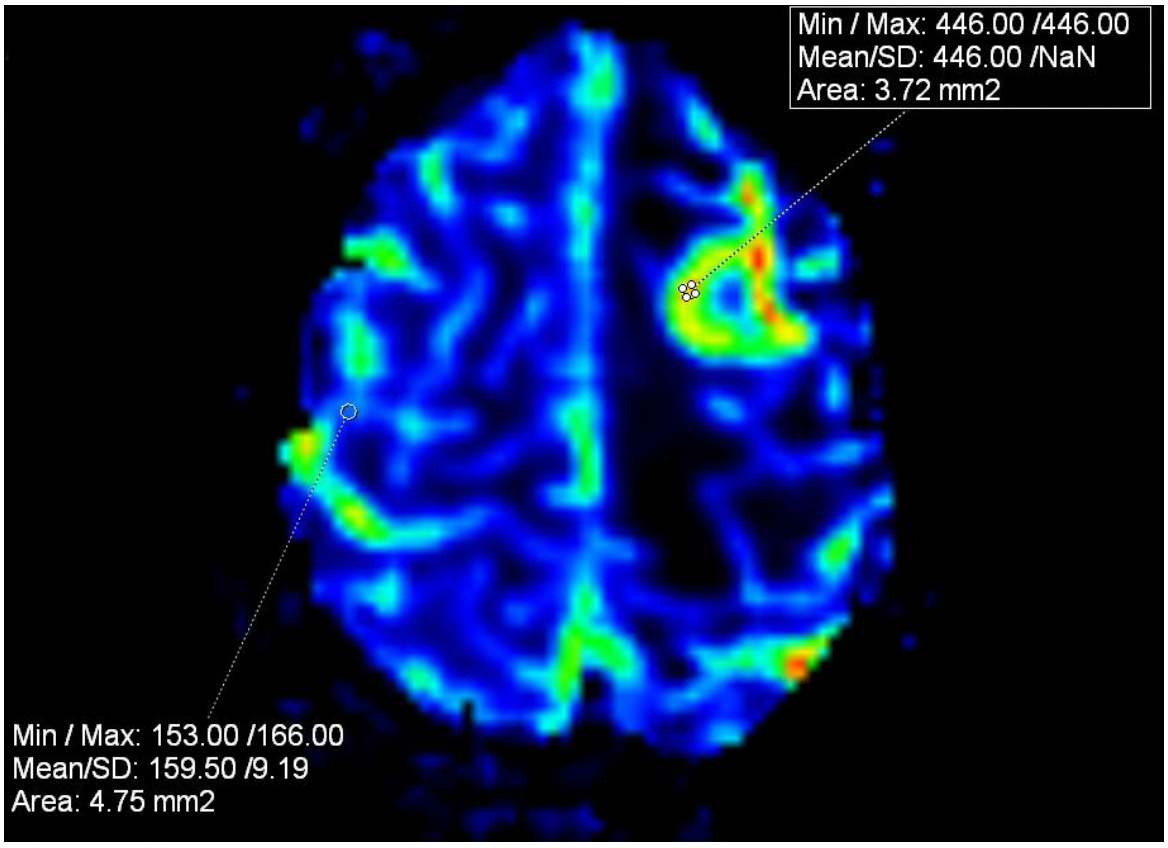


Picture 24: Case 6: Percentage signal recovery of the lesion is 70% and rPSR is 0.86.

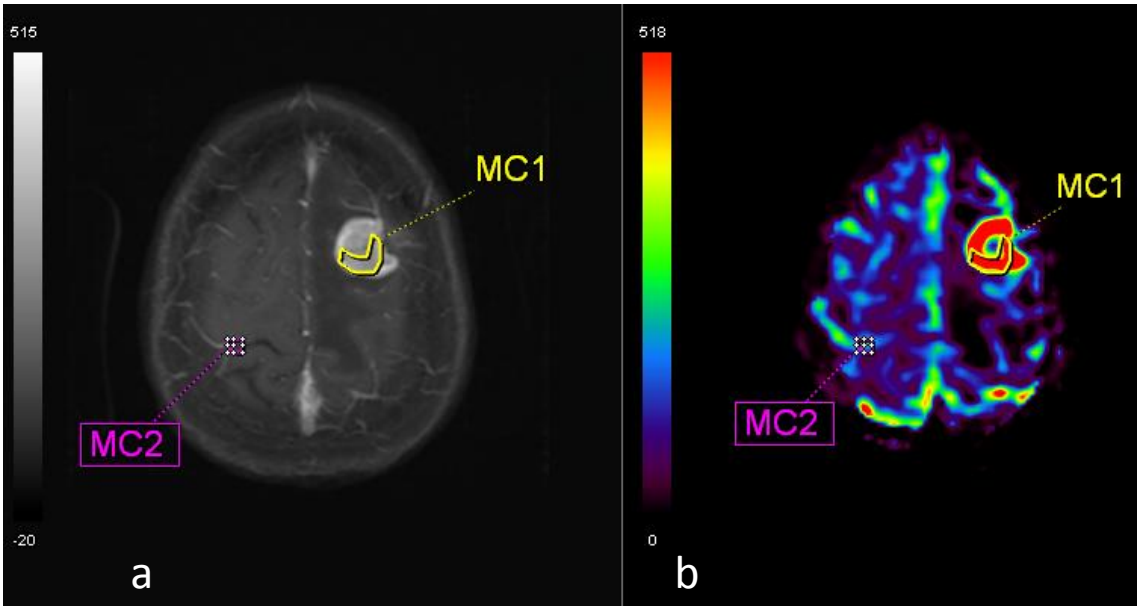


Picture 25: Case 7: 55-year-old female with carcinoma left breast. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in left high frontal lobe showing no diffusion restriction. Extensive perilesional white matter edema is noted.

a: DWI, b: ADC, c: FLAIR, and d: T1WI.

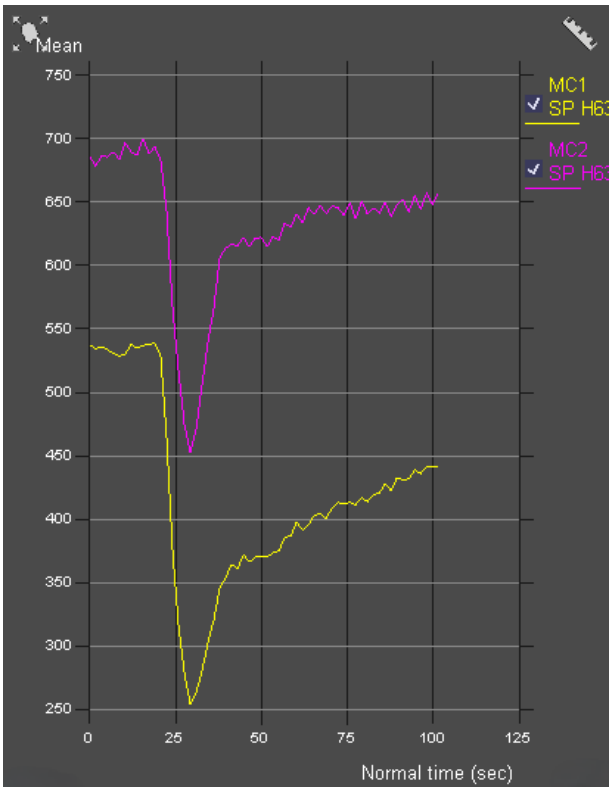


Picture 26: Case 7:CBF perfusion map shows rCBF value of 2.8 in the lesion.

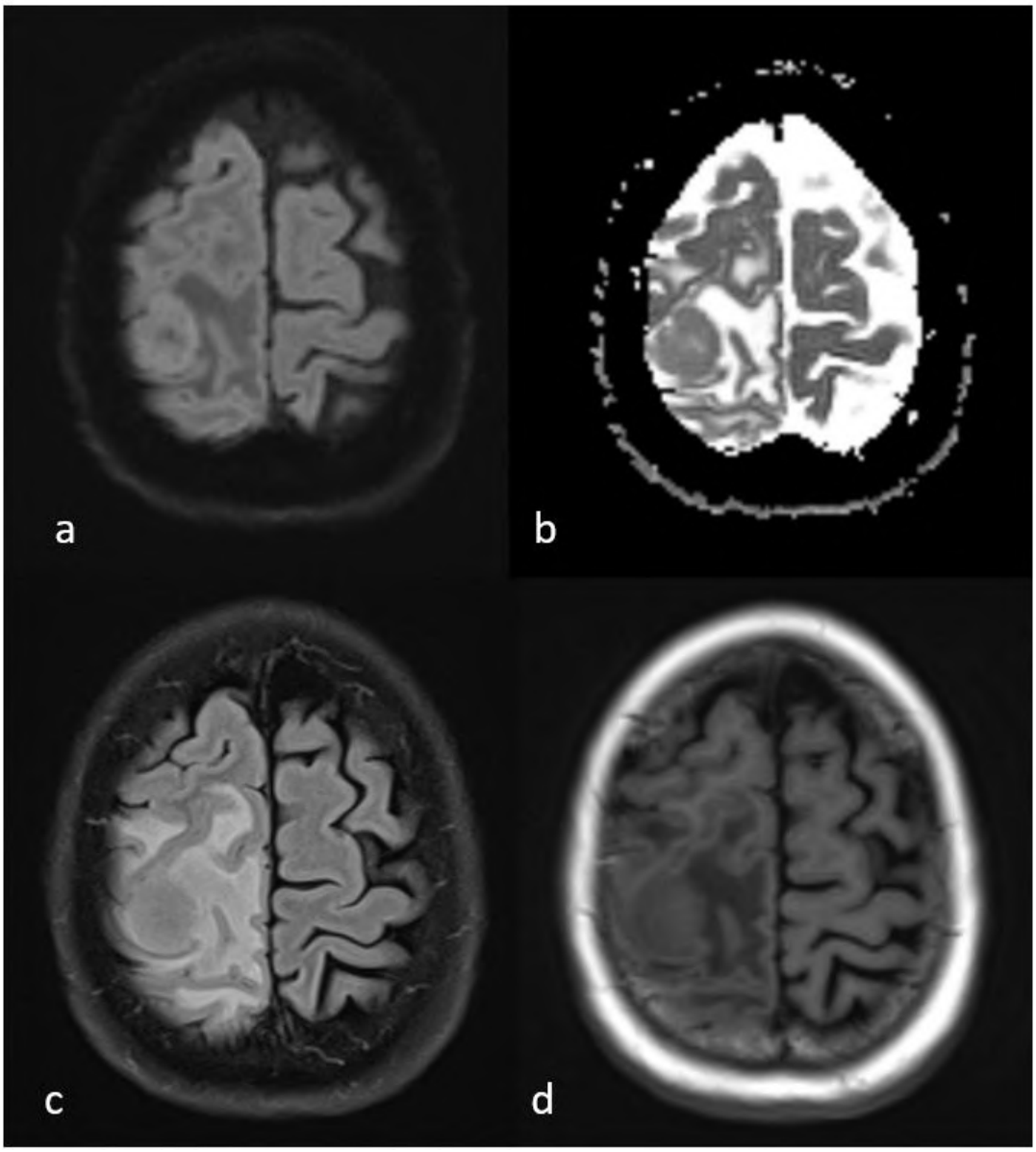


Picture 27: Case 7: Lesion shows solid post-contrast enhancement on T1WI.Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

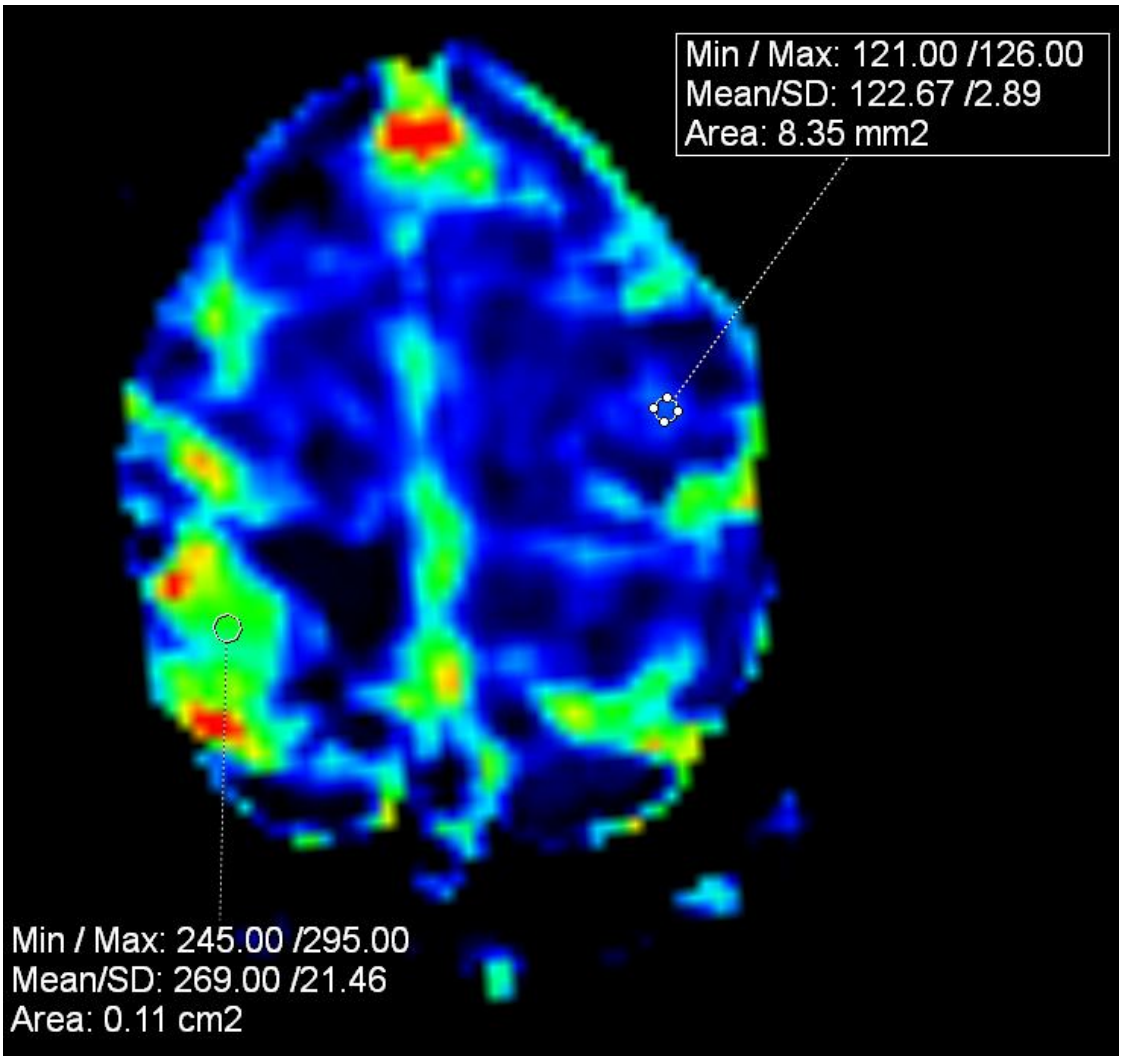


Picture 28: Case 7: Percentage signal recovery of the lesion is 38% and rPSR is 0.7.

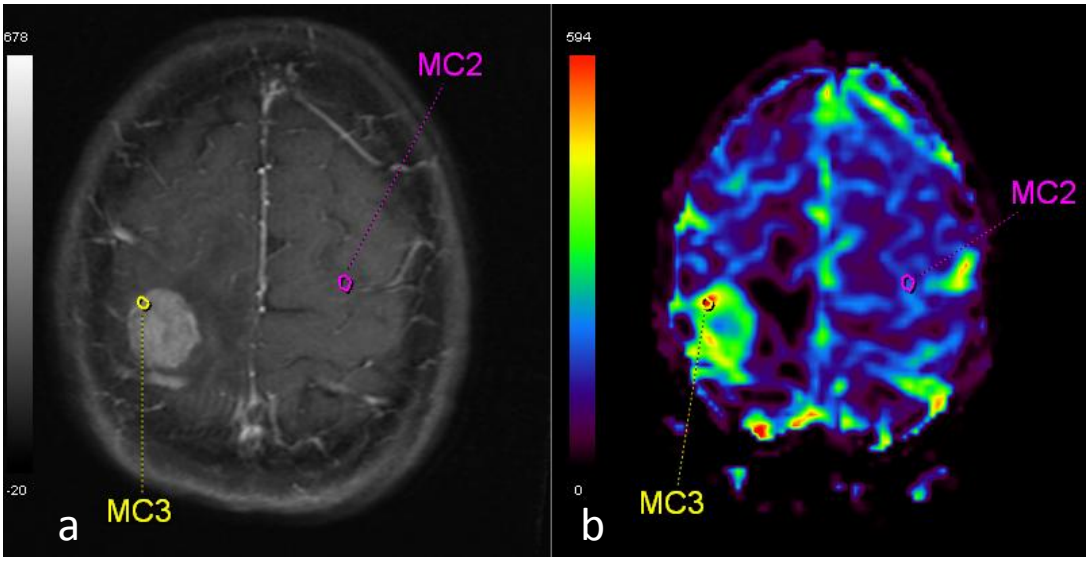


Picture 29: Case 8: 51-year-old female with carcinoma right breast. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in right frontal lobe showing no diffusion restriction. Extensive perilesional white matter edema is noted.

a: DWI, b: ADC, c: FLAIR, and d: T1WI.

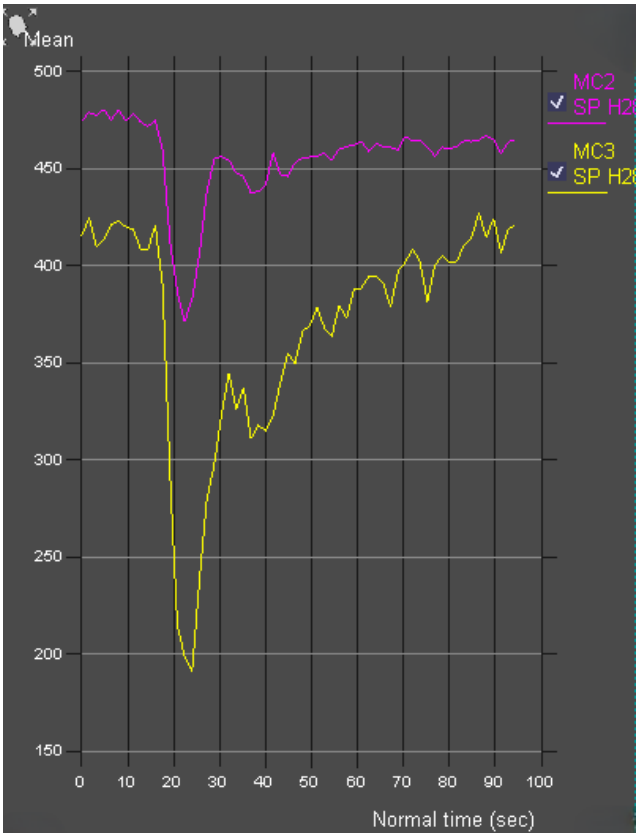


Picture 30: Case 8: CBF perfusion map shows rCBF value of 2.2 in the lesion.

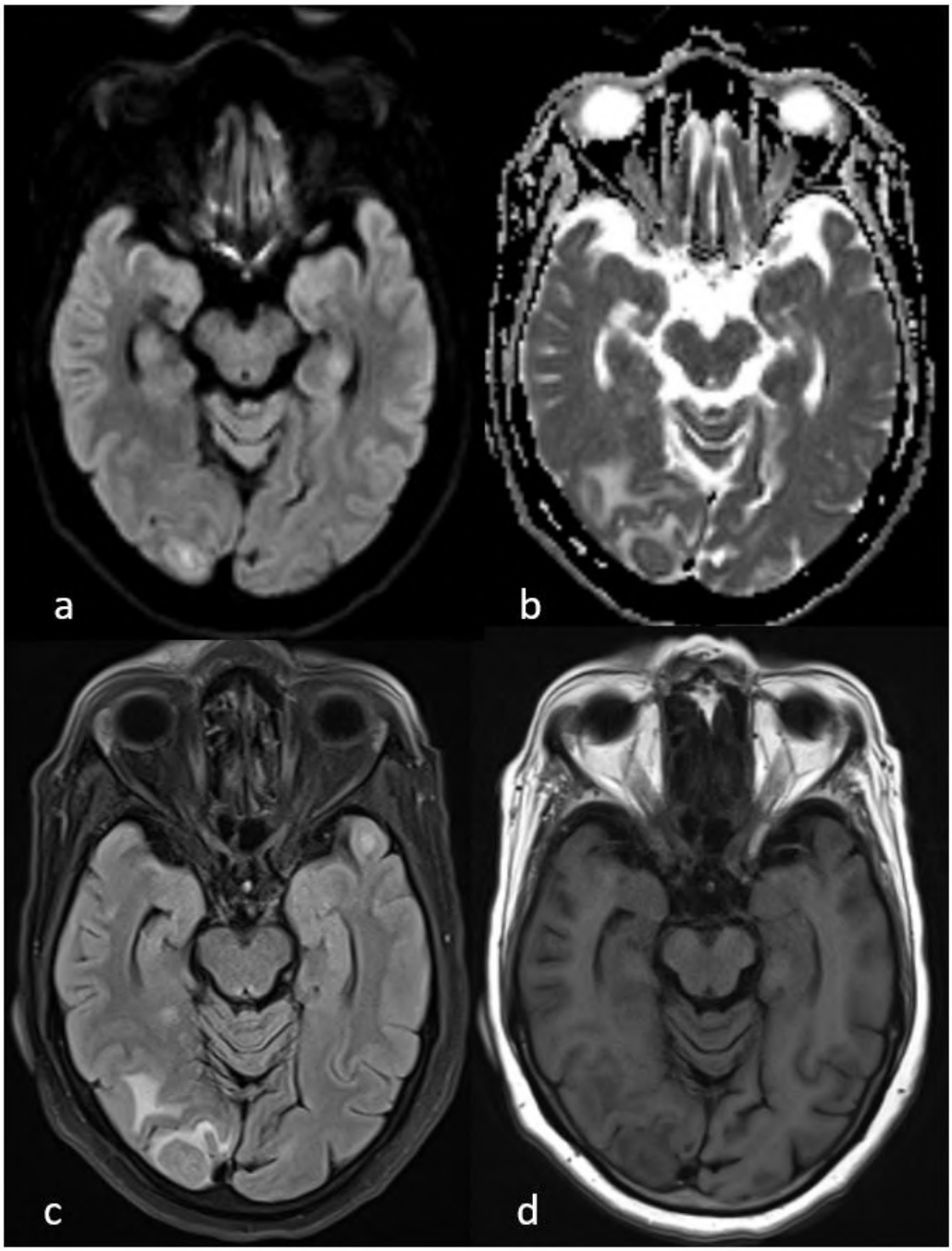


Picture 31: Case 8: Lesion shows vivid heterogenous post-contrast enhancement on T1WI.Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map

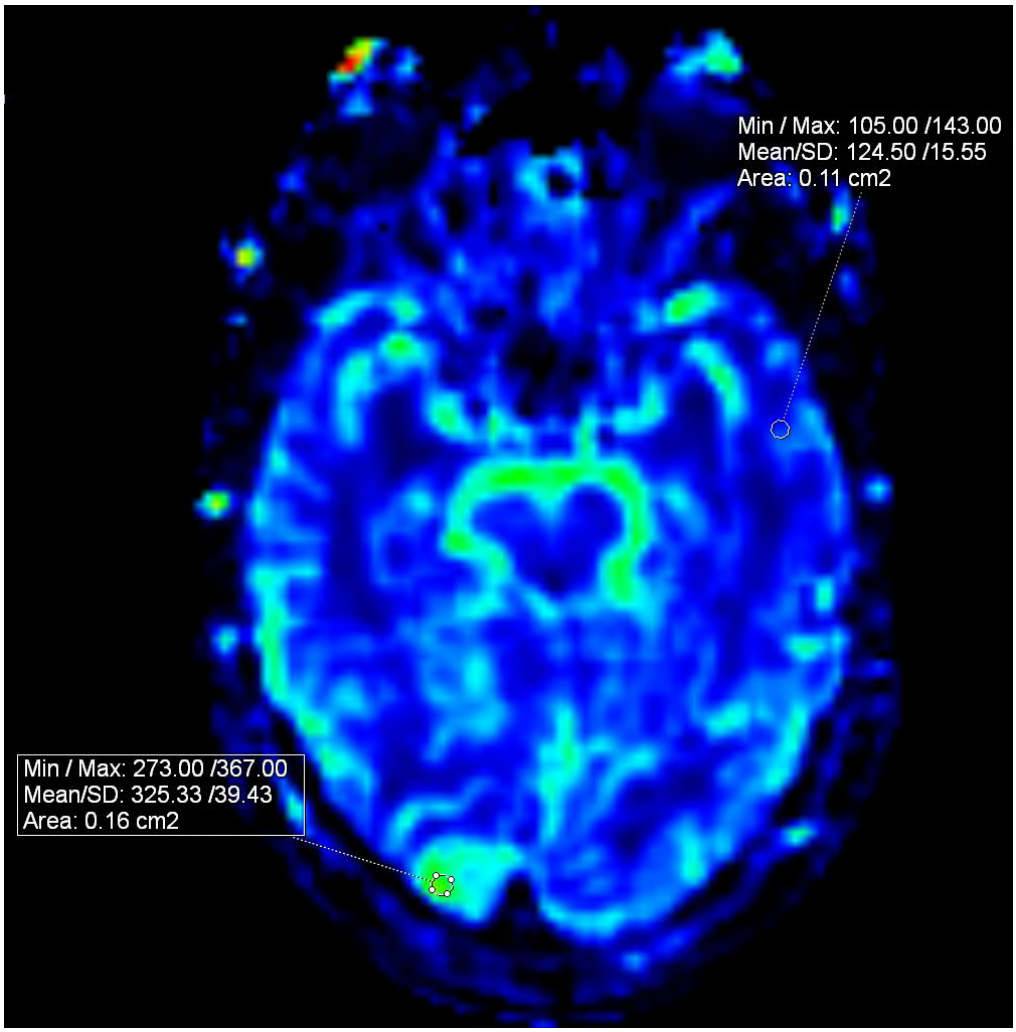


Picture 32: Case 8: Percentage signal recovery of the lesion is 54% and rPSR is 0.71.

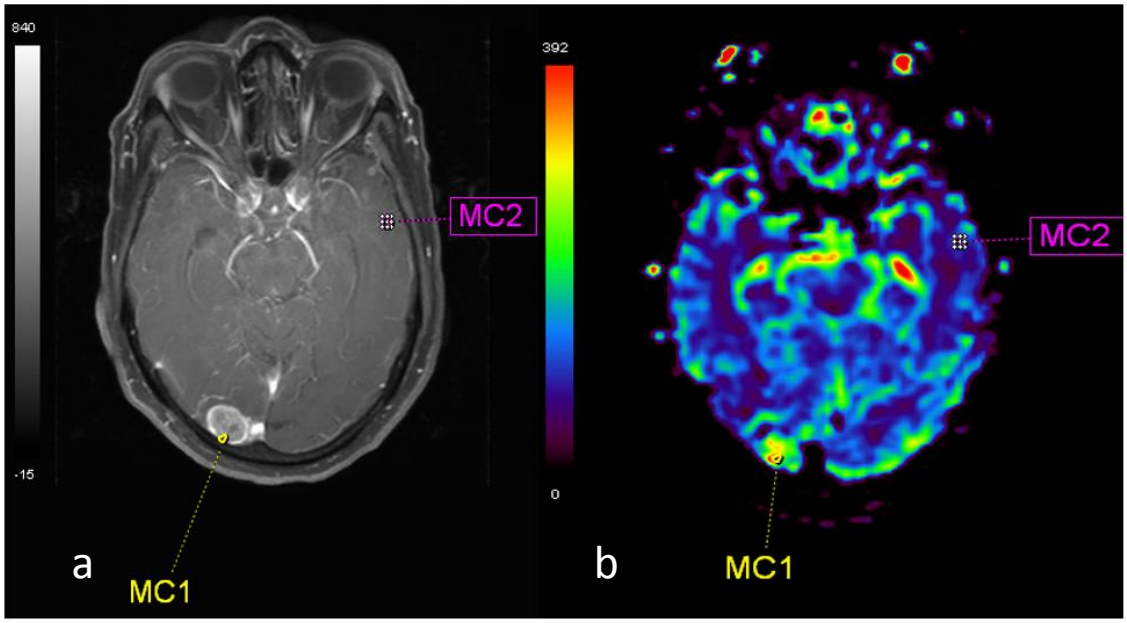


Picture 33: Case 9: 74-year-old female with adenocarcinoma pancreas. A well-defined lesion appearing isointense to the cortex on FLAIR and T1WI is seen in right occipital lobe with patchy diffusion. Mild perilesional white matter edema is noted.

a: DWI, b: ADC, c: FLAIR, and d: T1WI.

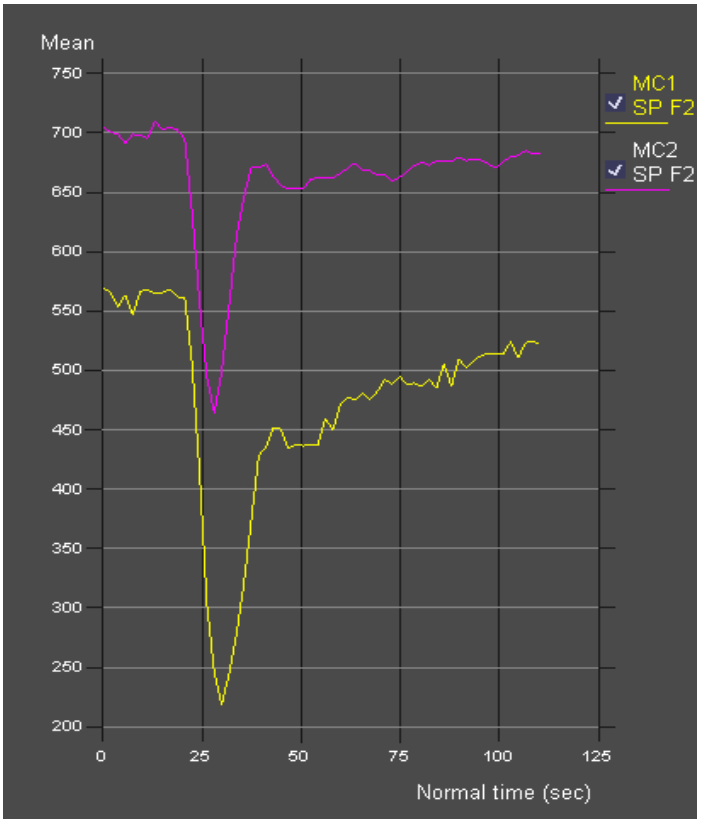


Picture 34: Case 9: CBF perfusion map shows rCBF value of 2.6 in the lesion.



Picture 35: Case 9: Lesion shows vivid heterogenous post-contrast enhancement on T1WI. Yellow ROI (MC1) is placed on the enhancing lesion on T1WI. Pink ROI (MC2) is placed on contralateral gray matter for normalization.

a: TIWI b: CBV perfusion map



Picture 36: Case 9: Percentage signal recovery of the lesion is 60% and rPSR is 0.7.

-	-	-	-	CHIEF COMPLAINTS							LAB INVESTIGATIONS				
-	-	-	-	-	-	-	-	-	-	-	HEMOGRAM			RFT	
S.NO	MRD NO	AGE	SEX	HEADCHE	NAUSEA	VOMITING	VERTIGO	PARALYSIS/PARESIS	SEIZURE	ANY OTHER	HB	TLC	PLATELETS	S.UREA	S.CREATININE
1	1413034	76	F	+	-	-	-	+	+	-	10.7	6.7	160	20	0.83
2	1359763	54	F	+	+	+	-	-	-	-	13.6	6.2	213	31	0.83
3	1395323	50	F	+	-	-	-	-	+	-	13.2	16.3	386	27	0.63
4	1391318	55	M	-	-	-	-	+	+	-	11.9	11.5	275	17	0.8
5	1399716	51	F	-	-	-	-	-	-	ALTERED SENSORIUM	12	11.4	434	26	0.78
6	1008971	57	M	+	-	-	-	-	-	-	14.9	6.9	141	24	0.69
7	1246628	74	F	-	-	-	-	-	-	WEAKNESS,SLURRING OF SPEECH	13.2	19.1	184	71	0.87
8	1033176	43	F	+	-	-	-	-	-	-	10	8.7	202	22	0.82
9	1351890	63	M	+	+	+	-	+ (RIGHT)	-	ATAXIA	15.2	9.3	238	37	1
10	1337674	62	M	+	-	+	+	-	+	-	12	6	230	24	1.23
11	1326332	66	M	-	-	-	-	+ (RIGHT UL)	-	ALTERED SENSORIUM	14.3	14.8	347	76	1.07
12	1233713	34	M	-	-	-	-	+	-	-	15.4	12.8	199	34	0.58
13	1340274	63	M	-	-	-	-	-	+	-	10.8	17.3	239	21	0.52
14	1389432	71	M	+	-	-	-	-	+	-	12.3	7.2	211	30	0.9
15	1442774	53	M	-	-	-	-	+ (LEFT)	-	-	16.8	8.3	229	36	0.69
16	1547947	65	F	+	-	-	-	-	-	-	11.9	15.5	154	30	1.06
17	1513146	44	M	+	-	-	-	-	-	-	13.3	12	224	24	0.9
18	1462015	40	M	+	-	-	-	-	-	-	14.8	8.6	195	36	0.73
19	1015735	74	M	-	-	-	-	+ (RIGHT)	-	HAND TREMOR	11.2	11.2	288	35	0.66

-	-	-	MRI FINDINGS						
-	-	-	T1W	T2W/FLAIR	CONTRAST ENHANCEMENT	-	DIFFUSION RESTRICTION	-	CONTRAST ENHANCEMENT PATTERN
S.NO	MRD NO	PROVISIONAL DIAGNOSIS	-	-	PRESENT	ABSENT	PRESENT	ABSENT	-
1	1413034	INTRACRANIAL BLEED	HYPOINTENSE TO ISOINTENSE	HYPOINTENSE	+	-	+	-	SOLID ENHANCEMENT
2	1359763	INTRACRANIAL SOL	HYPOINTENSE	HETEROGENEOUSLY HYPERINETNSE	+	-	+	-	PERIPHERAL THICK WALL
3	1395323	INTRACRANIAL SOL	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINETNSE	+	-	+	-	IRREGULAR PERIPHERAL
4	1391318	CVA	HYPOINTENSE	INTERMEDIATE	+	-	+	-	HOMOGENEOUS
5	1399716	INTRACRANIAL SOL	HYPOINTENSE	HETEROGENEOUSLY ISOINTENSE	+	-	+	-	HETEROGENEOUS
6	1008971	INTRACRANIAL SOL	ISOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	THICK NODULAR AND PERIPHERAL
7	1246628	CVA	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY ISOINTENSE	+	-	-	+	PERIPHERAL AND NODULAR
8	1033176	METASTASIS	HYPOINTENSE	HYPOINTENSE	+	-	-	+	NODULAR
9	1351890	CVA	HYPOINTENSE	HYPOINTENSE	+	-	+	-	HOMOGENEOUS
10	1337674	DEMYELINATION /INTRACRANIAL SOL	ISOINTENSE	HYPERINTENSE	+	-	+	-	PATCHY
11	1326332	CVA	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	THICK PERIPHERAL NODULAR
12	1233713	INTRACRANIAL SOL	HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	NODULAR RIM LIKE
13	1340274	INTRACRANIAL SOL	HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL
14	1389432	INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	PERIPHERAL RIND LIKE
15	1442774	CVA	HYPOINTENSE	HYPERINTENSE	+	-	+	-	THICK PERIPHERAL RIM LIKE
16	1547947	CVA	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL THICK RIND LIKE
17	1513146	CVA	HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL THICK RIND LIKE
18	1462015	INTRACRANIAL SOL	HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	HETEROGENEOUS
19	1015735	CVA	HYPOINTENSE	HYPOINTENSE	+	-	+	-	HOMOGENEOUS

-	-			PERFUSION PARAMETERS				-	-	-	-	-
-	-	SPECTROSCOPY	NUMBER OF ENHANCING	rCBV	rCBF	PSR	rPSR	RADIOLOGICAL DIAGNOSIS	HISTOPATHOLOGICAL DIAGNOSIS	CORRELATION WITH HISTOPATHOLOGY		PRIMARY IN CASE OF METASTASIS
S.NO	MRD NO	-	-	-	-	-	-	-	-	CONCORDANCE	DISCORDANCE	-
1	1413034	CHOLINE AND LIPID LACTATE PEAK	ONE	2.7	2.4	106%	1.3	? METASTASIS	DIFFUSE LARGE B CELL LYMPHOMA	-	+	-
2	1359763	CHOLINE PEAK	ONE	3.7	3.5	85%	0.96	POSSIBILITY OF GLIOMA RIGHT MEDIAL TEMPORAL LOBE	HIGH GRADE GLOMA	+	-	-
3	1395323	CHOLINE PEAK	ONE	3	2.8	67%	0.87	GBM RIGHT FRONTO TEMPORAL LOBE	HIGH GRADE GLOMA	+	-	-
4	1391318	CHOLINE AND LIPID LACTATE PEAK	ONE	1.7	1.6	138%	1.5	LYMPHOMA/GLIOMA/TUMEFACTIVE DEMYELINATION	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
5	1399716	CHOLINE PEAK	ONE	3.2	3.1	77%	0.96	CYSTIC MENINGIOMA/HYPERCELLULAR PRIMARY BRAIN TUMOR/METASTASIS	HIGH GRADE GLOMA	+	-	-
6	1008971	CHOLINE PEAK	ONE	6	5.5	93%	0.9	?GBM ?? METASTASIS	HIGH GRADE GLOMA	+	-	-
7	1246628	CHOLINE PEAK	MULTIPLE	2.8	2.7	66%	0.7	METASTASIS	METASTASIS	+	-	PANCREATICOBILIARY CARCINOMA
8	1033176	CHOLINE PEAK	MULTIPLE	2.5	2.2	63%	0.6	METASTASIS	METASTASIS	+	-	CARCINOMA BREAST
9	1351890	CHOLINE AND LIPID LACTATE PEAK	ONE	1.5	1.3	150%	1.5	POSSIBILITY OF LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
10	1337674	CHOLINE PEAK	ONE	2.6	2.5	74%	0.8	INFILTRATIVE GLIOMA	HIGH GRADE GLOMA	+	-	-
11	1326332	CHOLINE PEAK	MULTIPLE	6.8	6	62%	0.84	MULTICENTRIC GBM/METASTASIS/FUNGAL	HIGH GRADE GLOMA	+	-	-
12	1233713	CHOLINE PEAK	TWO	3.5	3.2	62%	0.77	HIGH GRADE GLIOMA LEFT TEMPORO PARIETAL LOBE	HIGH GRADE GLOMA	+	-	-
13	1340274	CHOLINE PEAK	ONE	3.4	3.2	77%	0.89	GBM RIGHT OCCIPITAL LOBE	HIGH GRADE GLOMA	+	-	-
14	1389432	CHOLINE PEAK	ONE	5	4	92%	1	CYSTIC GBM/METASTASIS	HIGH GRADE GLOMA	+	-	-
15	1442774	CHOLINE PEAK	MULTIPLE	3.6	3.5	92%	1	MULTICENTRIC / MULTIFOCAL GBM	HIGH GRADE GLOMA	+	-	-
16	1547947	CHOLINE PEAK	ONE	3	2.9	74%	0.8	INVASIVE MENINGIOMA > HIGH GRADE GLIOMA	HIGH GRADE GLOMA	-	+	-
17	1513146	CHOLINE PEAK	ONE	3	2.9	72%	0.84	GBM LEFT PARIETAL LOBE	HIGH GRADE GLOMA	+	-	-
18	1462015	CHOLINE PEAK	TWO	3.3	3	70%	0.76	POSSIBILITY OF HIGH GRADE GLIOMA LEFT FRONTAL LOBE	HIGH GRADE GLOMA	+	-	-
19	1015735	CHOLINE AND LIPID LACTATE PEAK	ONE	1.4	1.3	144%	1.7	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-

-	-	-	-	CHIEF COMPLAINTS							LAB INVESTIGATIONS				
-	-	-	-	-	-	-	-	-	-	-	HEMOGRAM			RFT	
S.NO	MRD NO	AGE	SEX	HEADCHE	NAUSEA	VOMITING	VERTIGO	PARALYSIS/PARESIS	SEIZURE	ANY OTHER	HB	TLC	PLATELETS	S.UREA	S.CREATININE
20	1580966	85	M	-	-	-	+	-	-	ATAXIA	8.9	3.35	285	22	0.64
21	1571282	68	M	-	-	-	-	-	-	MEMORY LOSS	13.4	7.18	160	22	0.89
22	1565520	48	F	+	-	-	+	-	+	-	9.7	9.9	453	43	0.87
23	1641340	58	M	+	-	-	-	+	+	-	16.9	11.4	285	27	1.02
24	1519840	64	F	-	-	-	-	+ (RIGHT)	-	-	13.7	11.3	240	31	0.72
25	1287767	67	F	-	-	-	-	-	-	SPONTANEOUS FALL	12.1	8.3	161	22	0.39
26	1290306	57	M	+	-	-	+	-	+	-	12.6	9.8	138	38	0.98
27	1315274	70	F	-	-	-	-	+	+	-	13	4.7	170	35	0.89
28	1315096	68	F	+	-	-	+	-	+	-	11.9	8	262	24	0.56
29	1326012	49	F	+	-	-	-	-	-	-	12.3	11.6	170	34	0.54
30	1235713	23	M	+	-	-	-	+	+	-	14.1	9.6	152	28	0.74
31	1660576	62	M	+	-	-	-	+ (LEFT)	+	-	15.1	7.6	170	36	0.76
32	1239059	57	M	+	-	-	-	+	+	-	11	7.9	130	37	0.7
33	1663238	65	F	-	-	-	-	-	-	LOSS OF CONSCIOUSNESS	13.8	13.8	261	26	0.71
34	1671638	52	M	+	+	+	-	-	-	-	13.9	11.9	211	22	0.52
35	1648826	55	M	+	-	-	+	-	+	-	10.4	6.6	277	12	0.66
36	1263047	65	F	-	-	-	-	+	-	-	11.9	8	283	59	1.3
37	1323632	57	F	-	-	-	-	-	+	-	12.3	4.8	332	17	0.58

-	-	-	MRI FINDINGS						
-	-	-	T1W	T2W/FLAIR	CONTRAST ENHANCEMENT	-	DIFFUSION RESTRICTION	-	CONTRAST ENHANCEMENT PATTERN
S.NO	MRD NO	PROVISIONAL DIAGNOSIS	-	-	PRESENT	ABSENT	PRESENT	ABSENT	-
20	1580966	INFARCT	INTERMEDIATE	INTERMEDIATE	+	-	+	-	IRREGULAR THICK RIM
21	1571282	INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	HETEROGENEOUS THICK PERIPHERAL AND IRREGULAR
22	1565520	INTRACRANIAL SOL	HYPOINTENSE	INTERMEDIATE	+	-	+	-	INTENSE HOMOGENEOUS
23	1641340	INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	PERIPHERAL THICK IRREGULAR
24	1519840	CVA	HYPOINTENSE	INTERMEDIATE	+	-	+	-	PERIPHERAL THICK WALLED
25	1287767	CVA	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL THICK RIND LIKE
26	1290306	CVA	HYPOINTENSE	HYPERINTENSE	+	-	+	-	PERIPHERAL
27	1315274	INTRACRANIAL SOL	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL THICK RIND LIKE
28	1315096	INTRACRANIAL SOL	HYPOINTENSE	HYPOINTENSE	+	-	+	-	HOMOGENEOUS
29	1326012	INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	THICK IRREGULAR PERIPHERAL AND NODULAR
30	1235713	INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	PATCHY NODULAR
31	1660576	INTRACRANIAL SOL	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	THICK PERIPHERAL
32	1239059	INTRACRANIAL SOL	ISOINTENSE	INTERMEDIATE	+	-	+	-	HETEROGENEOUS
33	1663238	CVA	HYPOINTENSE	HYPERINTENSE	+	-	+	-	THICK NODULAR
34	1671638	CHRONIC MENINGITIS/TUBERCULAR MENINGITIS	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL ENHANCEMENT
35	1648826	INTRACRANIAL BLEED/ CVT	HETEROGENEOUSLY HYPERINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	PERIPHERAL RING LIKE
36	1263047	CVA	HYPOINTENSE	HETEROGENEOUSLY HYPERINTENSE	+	-	+	-	MILD HOMOGENEOUS
37	1323632	LYMPHOMA/DEMYELINATION	HYPOINTENSE	HYPERINTENSE	+	-	+	-	SOLID NODULAR ENHANCEMENT

-	-			PERFUSION PARAMETERS				-	-	-	-	-
-	-	SPECTROSCOPY	NUMBER OF ENHANCING	rCBV	rCBF	PSR	rPSR	RADIOLOGICAL DIAGNOSIS	HISTOPATHOLOGICAL DIAGNOSIS	CORRELATION WITH HISTOPATHOLOGY		PRIMARY IN CASE OF METASTASIS
S.NO	MRD NO	-	-	-	-	-	-	-	-	CONCORDANCE	DISCORDANCE	-
20	1580966	CHOLINE PEAK	MULTIPLE	2.9	2.9	96%	1	?GBM	HIGH GRADE GLOMA	+	-	-
21	1571282	CHOLINE PEAK	ONE	3.4	3.2	74%	0.85	HIGH GRADE GLIOMA RIGHT FRONTAL LOBE	HIGH GRADE GLOMA	+	-	-
22	1565520	CHOLINE AND LIPID LACTATE PEAK	ONE	1.8	1.6	153%	1.8	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
23	1641340	CHOLINE PEAK	ONE	4	3	77%	0.81	?CYSTIC GLIOMA ? METASTATIC	HIGH GRADE GLOMA	+	-	-
24	1519840	CHOLINE PEAK	TWO	3.1	2.8	83%	0.9	HIGH GRADE GLIOME> METASTASIS	HIGH GRADE GLOMA	+	-	-
25	1287767	CHOLINE PEAK	ONE	3	2.9	72%	1	GRADE IV GLIOMA	HIGH GRADE GLOMA	+	-	-
26	1290306	CHOLINE PEAK	ONE	3.2	3	82%	0.9	HIGH GRADE GLIOMA	HIGH GRADE GLOMA	+	-	-
27	1315274	CHOLINE PEAK	ONE	3.2	3	63%	0.9	GLIOBLASTOMA MULTIFORME RIGHT TEMPORAL LOBE	HIGH GRADE GLOMA	+	-	-
28	1315096	CHOLINE AND LIPID LACTATE PEAK	ONE	1.6	1.5	160%	1.7	PRIMARY CNS LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
29	1326012	CHOLINE PEAK	ONE	3.3	3.1	73%	0.8	GBM	HIGH GRADE GLOMA	+	-	-
30	1235713	CHOLINE PEAK	ONE	3.5	3.5	89%	1	POSSIBILITY OF GBM D/D LYMPHOMA	HIGH GRADE GLOMA	+	-	-
31	1660576	CHOLINE PEAK	ONE	3.4	3	77%	0.9	HIGH GRADE GLIOMA	HIGH GRADE GLOMA	+	-	-
32	1239059	CHOLINE PEAK	ONE	3.8	3.5	68%	0.93	GLIOBLASTOMA MULTIFORME	HIGH GRADE GLOMA	+	-	-
33	1663238	CHOLINE PEAK	TWO	3.7	3.6	61%	0.8	METASTASIS D/D MULTICENTRIC HIGH GRADE GLIOMA	HIGH GRADE GLOMA	+	-	-
34	1671638	CHOLINE PEAK	ONE	3.5	3.1	86%	0.98	HIGH GRADE GLIOMA	HIGH GRADE GLOMA	+	-	-
35	1648826	CHOLINE PEAK	ONE	3.1	3	83%	0.8	HEMORRHAGIC METASTASIS/GBM	HIGH GRADE GLOMA	+	-	-
36	1263047	CHOLINE AND LIPID LACTATE PEAK	ONE	1.6	1.6	100%	1	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
37	1323632	CHOLINE AND LIPID LACTATE PEAK	ONE	1.5	1.3	127%	1.5	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-

-	-	-	-	CHIEF COMPLAINTS							LAB INVESTIGATIONS				
-	-	-	-	-	-	-	-	-	-	-	HEMOGRAM			RFT	
S.NO	MRD NO	AGE	SEX	HEADCHE	NAUSEA	VOMITING	VERTIGO	PARALYSIS/PARESIS	SEIZURE	ANY OTHER	HB	TLC	PLATELETS	S.UREA	S.CREATININE
38	1282002	55	F	+	-	-	-	-	-	-	10.9	7.08	189	30	0.89
39	1044952	49	F	+	-	-	+	+	-	-	11.5	7.2	234	24	0.51
40	1290245	75	F	-	-	-	-	-	-	INCREASED DROWSINESS AND LOSS OF CONSCIOUSNESS	11.7	4.9	310	34	0.81
41	923556	48	M	+	-	-	+	-	-	-	14.8	7.1	193	16	1.24
42	1330896	65	M	+	-	-	+	-	-	-	9.9	5.03	415	24	0.86
43	1702042	49	F	+	-	-	-	-	-	-	13	5.4	159	30	0.7
44	1385001	50	M	-	-	-	-	-	+	-	12.6	7.96	206	23	0.85
45	1426450	51	F	+	-	-	-	-	-	-	11.5	6.1	320	27	0.66
46	1449808	40	F	+	-	-	-	-	-	-	11.3	9.8	402	30	0.76
47	1560192	77	F	-	-	-	-	+ (LEFT)	-	-	9.5	8.5	254	32	0.55
48	911336	45	F	+	-	-	-	-	-	-	8.8	8.9	260	27	0.71
49	1708023	62	F	+	-	-	-	-	-	-	6.5	5.1	125	18	0.06
50	1501706	75	M	-	-	-	-	-	-	JERKY LEFT UPPER LIMB MOVEMENTS	11	9.12	170	35	1

-	-	-	MRI FINDINGS						
-	-	-	T1W	T2W/FLAIR	CONTRAST ENHANCEMENT	-	DIFFUSION RESTRICTION	-	CONTRAST ENHANCEMENT PATTERN
S.NO	MRD NO	PROVISIONAL DIAGNOSIS	-	-	PRESENT	ABSENT	PRESENT	ABSENT	-
38	1282002	METASTASIS	HYPOINTENSE	HYPERINTENSE	+	-	+	-	VIVID HETEROGENEOUS
39	1044952	METASTASIS	HYPOINTENSE	ISOINTENSE	+	-	+	-	PERIPHERAL ENHANCEMENT WITH ENHANCING SOLID COMPONENT
40	1290245	CHRONIC MENINGITIS/CVA	HYPOINTENSE	ISOINTENSE	+	-	+	-	HOMOGENEOUS
41	923556	METASTASIS	HYPOINTENSE	HYPERINTENSE	+	-	+	-	THICK PERIPHERAL NODULAR
42	1330896	NONE	HYPOINTENSE	HYPERINTENSE	+	-	+	-	PERIPHERAL THICK RING LIKE
43	1702042	METASTASIS	ISOINTENSE TO HYPOINTENSE	ISOINTENSE TO HYPOINTENSE	+	-	+	-	HETEROGENEOUS
44	1385001	DEMYELINATION /INTRACRANIAL SOL	HYPOINTENSE	HYPERINTENSE	+	-	+	-	HETEROGENEOUS
45	1426450	METASTASIS	HETEROGENEOUSLY HYPOINTENSE	HETEROGENEOUSLY HYPOINTENSE	+	-	+	-	NODULAR AND PERIPHERAL RIM
46	1449808	METASTASIS	HYPOINTENSE	HYPERINTENSE	+	-	+	-	IRREGULAR PERIPHERAL
47	1560192	CVA	HYPOINTENSE	HYPERINTENSE	+	-	+	-	SOLID COMPONENT WITH ENHANCEMENT
48	911336	METASTASIS	HYPOINTENSE	HYPOINTENSE	+	-	+	-	HETEROGENEOUS PERIPHERAL
49	1708023	INTRACRANIAL SOL	HYPOINTENSE	ISOINTENSE TO HYPOINTENSE	+	-	-	+	DIFFUSE, NODULAR AND RING LIKE
50	1501706	INTRACRANIAL SOL	HYPOINTENSE	HYPOINTENSE	+	-	+	-	INTENSE HOMOGENEOUS

-	-			PERFUSION PARAMETERS				-	-	-	-	-
-	-	SPECTROSCOPY	NUMBER OF ENHANCING	rCBV	rCBF	PSR	rPSR	RADIOLOGICAL DIAGNOSIS	HISTOPATHOLOGICAL DIAGNOSIS	CORRELATION WITH HISTOPATHOLOGY		PRIMARY IN CASE OF METASTASIS
S.NO	MRD NO	-	-	-	-	-	-	-	-	CONCORDANCE	DISCORDANCE	-
38	1282002	CHOLINE PEAK	ONE	6	4.5	49%	0.7	METASTASIS	METASTASIS	-	-	CARCINOMA BREAST
39	1044952	-	THREE	1.8	1.5	56%	0.8	METASTASIS	METASTASIS	-	-	CARCINOMA BREAST
40	1290245	CHOLINE AND LIPID LACTATE PEAK	ONE	1.6	1.4	129%	1.6	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
41	923556	CHOLINE PEAK	ONE	3.4	3	58%	0.78	METASTASIS	METASTASIS	-	-	RENAL CELL CARCINOMA
42	1330896	CHOLINE PEAK	MULTIPLE	3.5	3.2	51%	0.63	METASTASIS	METASTASIS	-	-	CARCINOMA LUNG
43	1702042	CHOLINE PEAK	TWO	3.8	3.6	65%	0.8	METASTASIS	METASTASIS	-	-	CARCINOMA BREAST
44	1385001	CHOLINE AND LIPID LACTATE PEAK	ONE	1.4	1.2	110%	1.2	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-
45	1426450	CHOLINE PEAK	MULTIPLE	2.9	2.8	54%	0.7	METASTASIS	METASTASIS	-	-	CARCINOMA BREAST
46	1449808	CHOLINE PEAK	MULTIPLE	3.2	3	60%	0.8	METASTASIS	METASTASIS	-	-	PANCREATICOBILIARY CARCINOMA
47	1560192	-	MULTIPLE	2.2	1.7	51%	0.7	METASTASIS	METASTASIS	-	-	CARCINOMA LUNG
48	911336	CHOLINE PEAK	MULTIPLE	4	3.5	61%	0.8	METASTASIS	METASTASIS	-	-	CARCINOMA BREAST
49	1708023	CHOLINE PEAK	ONE	3.3	3.2	82%	0.85	BUTTERFLY GLIOMA VS LYMPHOMA	HIGH GRADE GLOMA	+	-	-
50	1501706	CHOLINE AND LIPID LACTATE PEAK	ONE	1.6	1.4	130%	1.4	LYMPHOMA	DIFFUSE LARGE B CELL LYMPHOMA	+	-	-

Baba Farid University
of Health Sciences
Sadiq Road
Faridkot-151 203 (Pb). INDIA.
Phone : 01639-256232,256236
Tele/Fax : 01639-256235
Email – Thesisbfuhs@gmail.com

56

No. BFUHS/2K23p-TH/ 41 Date 1/1/24

The Principal
Dayanand Medical College & Hospital
Ludhiana

Subject:: Approval of Plan of Thesis.

This is to inform you that the Faculty of Medical Sciences in its meeting held on 25.09.2023 has approved the plan of thesis of **Ananya Singh**, a student of your college for **MD Radio-diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis
Role of perfusion parameters and percentage signal recovery derived from mr dynamic susceptibility contrast imaging in enhancing intra-axial brain tumors .

Supervisor	Co-Supervisor:-	Co-Supervisor:-
Dr. Kavita Saggar	Dr. Harpreet Kaur	Dr. Devinderpal Singh Dhanota
Prof. & Head,	Prof. & Head	Asst. Professor
Dept. of Radiodiagnosis	Dept. of Pathology	Dept. of Radiodiagnosis

The student may submit the thesis in triplicate alongwith the plan in triplicate also, to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She may be directed to attach a photocopy of this letter with the forwarding letter while submitting thesis in the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic, if any.

Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*

ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MD

In

RADIODIAGNOSIS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES

FARIDKOT

AUGUST, 2022

DR. ANANYA SINGH

DEPARTMENT OF RADIODIAGNOSIS
DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA

ABSTRACT OF PLAN OF THESIS

Title	**ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS**
For the degree of	MD Radiodiagnosis
Name of the candidate	Dr. Ananya Singh
Supervisor	Dr. Kavita Saggar, Professor& Head, Department of Radio-diagnosis,DMCH, Ludhiana
Co-supervisor(s)	Dr. Harpreet Kaur, Professor& Head, Department of Pathology, DMCH, Ludhiana Dr. Devinderpal Singh Dhanota, Assistant Professor, Department of Radio-diagnosis DMCH, Ludhiana
Institution	Dayanand Medical College and Hospital, Ludhiana.
University	Baba Farid University of Health Sciences, Faridkot.

Introduction: The characterization and differentiation of intracranial malignant lesions such as gliomas, metastases, and lymphoma can be challenging as there is considerable overlap in their imaging features. The differentiation of these enhancing malignant lesions is often required because their management differ substantially. These tumors differ in hemodynamics in terms of endothelial hyperplasia, vascular density, capillary permeability, loss of blood brain barrier (BBB), integrity and neo-angiogenesis. Percentage Signal Recovery (PSR), a novel perfusion parameter obtained from T2 DSC MR imaging, has been suggested to be better quantitative parameter than rCBV for differentiation of these tumors.

Aim Of Study: To evaluate the role of Perfusion Parameters and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.

Materials and Methods: This study will be conducted over a period of one and half year from 15th Sep 2022 to 15th March 2024 on patients who will be referred to our institution Dayanand Medical College and Hospital for MR Brain in the Department of Radio-diagnosis with clinical suspicion of brain tumor.

Clinical Significance: To identify the role of Perfusion Parameters and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in pre-operative differentiation and characterization of enhancing intra-axial brain tumors as management and prognosis can alter substantially based on nature of lesion as these tumors have considerable overlap in their imaging features.

Keywords: percentage signal intensity recovery (PSR), dynamic susceptibility weighted contrast enhanced (DSC).

(Signature)	(Signature)	(Signature)	(Signature)	(Signature)
Candidate	Co-supervisor	Co-supervisor	Supervisor	Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate herself under our supervision and guidance.

Supervisor

Dr. Kavita Saggar
Professor& Head
Department of Radiodiagnosis
DMCH, Ludhiana

Co-Supervisor

Dr. Harpreet Kaur
Associate Professor
Department of Pathology
DMCH, Ludhiana

Dr. Devinderpal Singh Dhanota
Assistant Professor
Department of Radiodiagnosis
DMCH,Ludhiana

Head of the Department

Dr. Kavita Saggar
Professor & Head
Department of Radiodiagnosis
DMCH, Ludhiana

Place : _____
Date : _____

APPROVAL PROFORMA
BY RESEARCH & ETHICAL COMMITTEE
DAYANAND MEDICAL COLLEGE & HOSPITAL, LUDHIANA

Name of candidate	Dr. Ananya Singh
Department	Radiodiagnosis
Topic of Thesis	ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS
Likely date of appearing in PG examination	May/June, 2024
Date of enrollment	February 21, 2022
Name of Head of Department	Dr. Kavita Saggar
1) Supervisor **2) Co-Supervisor(s)**	Dr. Kavita Saggar Dr. Harpreet Kaur, Dr. Devinderpal Singh Dhanota
Signature of Members of Research Committee with Stamp	**Signature of Members of Ethics Committee with Stamp**
Dr. Harpreet Kaur (Professor & Head, Pathology)	Mr. R K Sharma (Legal Expert)
Dr. Jaspal Singh (Professor & Head, Surgery)	Dr. Ramit Mahajan (Associate Professor, Gastroenterology)
Dr. Dinesh Gupta (Professor & Head, Medicine)	Dr. Anu Sharma (Professor, Anatomy)
Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)	Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)
Dr. Gurpreet S Wander (Vice Principal)	Dr. Gurpreet S Wander (Vice Principal & Professor & Head, Cardiology)
	Dr. Gagandeep Singh (Secretary, Ethics Committee Professor & Head, Neurology)

Approved: Yes / ~~No~~

Dr. Sandeep Puri
Chairperson
Research Committee

Chairperson
Research Committee

Approved: Yes / ~~No~~

Prof. Arvind Malhotra
Chairperson
Ethics Committee

Chairperson
Ethics Committee

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

1	NAME OF THE CANDIDATE AND ADDRESS	Dr. Ananya Singh 285\1, Hayer Vihar, Near Panj Pir, Babowal Road, Gurdaspur, 143521
2	NAME OF THE INSTITUTE	Dayanand Medical College and Hospital, Ludhiana.
3	COURSE OF STUDY AND SUBJECT	M.D Radiodiagnosis
4	DATE OF ADMISSION OF COURSE	21 February 2022
5	TITLE OF THE TOPIC	Role of perfusion parameters and percentage signal recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

To evaluate diagnostic performance and accuracy of Perfusion Parameters and Percentage Signal Recovery in differentiation of common brain tumors including gliomas, primary central nervous lymphoma (PCNSL) and metastases as the differentiation may be challenging on standard magnetic resonance (MR) imaging due to similarities in their appearances. These tumors differ in hemodynamics in terms of endothelial hyperplasia, vascular density, capillary permeability, loss of blood brain barrier (BBB), integrity and neo-angiogenesis.[1-2] Management differ substantially depending upon the type of lesion. Diffusion and relative cerebral blood volume (rCBV) measurements with perfusion weighted sequences have highlighted some salient features in the lesions but these are not always confirmatory.[3-5] DSC MR perfusion imaging has been used to assess the status of the capillaries and micro-vessel attenuation of the tumors. Changes in rCBV maps, which reflect the micro vessel attenuation, are markers of neo angiogenesis taking place within the lesion, and rCBV has become one of the most important hemodynamic variables used in characterization of tumors. rCBV mainly reflects neovascularity of the lesion but does not provide information on capillary permeability. rCBV is higher for high-grade gliomas and metastases than low-grade gliomas and primary central nervous lymphoma (PCNSL). Such a difference may be attributed to the status of neovascularity which is lacking in the primary central nervous lymphoma (PCNSL) and is lesser in low-grade gliomas.[6-7] Thus is has been suggested that rCBV is considerably higher in glioblastomas and has been used on grading of gliomas.[8] In primary central nervous lymphoma (PCNSL) , rCBV is lower than in gliomas and metastases due to lack of neo angiogenesis.[9] There is overlap in rCBV values in case of gliomas and metastases because both have high rCBV. Percentage Signal Recovery is thus a better criterion for differentiating these lesions. Percentage Signal Recovery represents the percentage of signal

intensity that is recovered at the end of the first pass of contrast agent, relative to baseline. There is an initial drop in signal intensity after administration of contrast agent, which after the first pass returns towards baseline. The degree of this recovery is dependent on many factors related to contrast agent leakage, the size of extravascular space and the rate of blood flow.[10] There are reports of significantly reduced Percentage Signal Recovery in metastatic lesions compared with Glioblastoma multiforme (GBM).[10] Glioblastoma multiforme has been reported to have a lower recovery of signal intensity than primary CNS lymphoma. The recovery curve in lymphoma can go above the baseline (overshooting).[11-12] Preoperative differentiation and characterization of these lesions is important as management and hence prognosis can alter substantially based on nature of the lesion.[13] Preoperative diagnosis of lymphoma is extremely important as it can avoid extensive unnecessary surgery for tumor removal, thus a smaller biopsy for tissue characterization will be sufficient for treatment decisions.[14-16] History of primary malignancy or presence of multifocal lesions may assist in the diagnosis of metastases, but differentiation is often difficult when patients present with a solitary enhancing mass of unknown primary.[17] Metastases can be the first manifestation of a systemic malignancy so it is important to differentiate between these lesions.[18] The standard treatment of Glioblastoma multiforme (GBM) and metastases consists of surgical resection, radiotherapy and chemotherapy while primary central nervous lymphoma (PCNSL) should not undergo a surgical management but only chemotherapy.[19-22] Although histopathological tissue evaluation is the current standard for classifying primary brain tumors, the drawbacks of this invasive procedure have led to demand of developing reliable preoperative differentiation methods.[23-24]

6.2 REVIEW OF LITERATURE

S. Cha et al (2007) evaluated forty-three patients with histopathologic diagnosis of GBM (n = 27) or MET (n = 16) who underwent DSC perfusion MR imaging in addition to anatomic MR imaging before surgery. Regions of interest were drawn around the nonenhancing peritumoral T2 lesion (PTL) and the contrast-enhancing lesion (CEL). T2* signal intensity-time curves acquired during the first pass of gadolinium contrast material were converted to the changes in relaxation rate to yield T2* relaxivity (ΔR2*) curve. The peak height of maximal signal intensity drop and the percentage of signal intensity recovery at the end of first pass were measured for each voxel in the PTL and CEL regions of the tumor.The average peak height for the PTL was significantly higher in GBM than in MET. The average percentage of signal intensity recovery was significantly reduced in PTL and in CEL regions of MET compared with those regions in the GBM group.The findings showed that the peak height and the percentage of signal intensity recovery derived from the ΔR2* curve of DSC perfusion MR imaging can differentiate GBM and MET.[10]

R. Mangla et al (2011) evaluated 66 patients with pathologically proven diagnosis of primary CNS lymphoma, GBM and metastases (22 patients in each group). Mean PSR, min PSR, max PSR, and rCBV were calculated. Theclassification accuracy of these parameters was investigated by using ROC.

Mean PSR was high in lymphoma, intermediate in GBM and low in metastases with a P value <.000. F values obtained from 1-way ANOVA analysis for mean, min, and max PSR ratios which were betterthan those of rCBV in differentiating the 3 groups. In conclusion PSR appears to be a parameter that helps in differentiating intracerebral malignant lesions such as GBM, metastases and lymphoma.[1]

M.D.Lee et al (2019) retrospectively analyzed DSC-MR imaging of treatment-naïve, pathology-proved glioblastomas (n = 14), primary central nervous system lymphomas (n = 7), metastases (n = 20), and meningiomas (n = 13) using a protocol designed for relative CBV

accuracy. Mean percentage signal recovery, relative CBV, and normalized baseline signal intensity were compared within contrast-enhancing lesion volumes. Classification accuracy was determined by receiver operating characteristic analysis.Relative CBV best differentiated meningioma from glioblastoma and from metastasis with areas under the curve of 0.84 and 0.82, respectively. The percentage signal recovery best differentiated primary central nervous system lymphoma from metastasis with an area under the curve of 0.81. Relative CBV and percentage signal recovery were similar in differentiating primary central nervous system lymphoma from glioblastoma and from meningioma. Although neither relative CBV nor percentage signal recovery differentiated glioblastoma from metastasis, mean normalized baseline signal intensity achieved 86% sensitivity and 50% specificity.Similar to results for non-preload-based DSC-MR imaging, percentage signal recovery for one-quarter-dose preload-based, intermediate flip angle DSC-MR imaging differentiates most pair-wise comparisons of glioblastoma, metastasis, primary central nervous system lymphoma, and meningioma, except for glioblastoma versus metastasis. Differences in normalized post-preload baseline signal for glioblastoma and metastasis, reflecting a snapshot of dynamic contrast enhancement, may motivate the use of single-dose multiecho protocols permitting simultaneous quantification of DSC-MR imaging and dynamic contrast-enhanced MR imaging parameters.[26]

KL Surendra el al (2020) evaluated pathologically confirmed cases of 10 low-grade glioma, 22 high-grade glioma, 6 lymphoma, and 12 metastases (Total 50). PSR, relative PSR (rPSR), and rCBV were calculated.Accuracy of these parameters studied statistically using analysis of variance and ROC (Receiver operating characteristic) curves. rCBV was higher in metastases and high-grade glioma, whereas was low in lymphoma and low-grade glioma with P value of 0.030. PSR was low in metastases,intermediate in glioma and high in lymphoma with P value < 0.000. rPSR was higher for lymphoma than high-grade glioma and metastasis with P value <.000. Area under ROC for PSR was greater than rCBV in differentiating metastases from

lymphoma, high-grade glioma from lymphoma, high-grade glioma from metastases, and high-grade glioma from low-grade glioma with excellent curve characteristics. F values for PSR and rPSR from ANOVA analysis were better than rCBV in differentiating these groups.Percentage of signal recovery shows low recovery values in metastases, intermediate recovery values in glioma, and overshoot in lymphoma. PSR values show lower overlap than rCBV between lymphoma and metastases; and between high grade glioma and metastases. PSR difference is also higher than rCBV between low- and high-grade gliomas. Hence, PSR can potentially help as an additional perfusion parameter in the preoperative differentiation of these tumors.[13]

Emetullah Cindil et al (2021) evaluated 99 solitary enhancing tumors (60 HGGs, 24 metastases, 15 PCNSLs) before treatment. rCBV, PSR, ADC in the tumor core and rCBV, and ADC in peritumoral edema were measured. The differences were evaluated using one-way ANOVA, and the diagnostic performance was evaluated using ROC curve analysis. PSR in the tumor core showed the best discriminating performance in differentiating these three tumor types with AUC values of 0.979 for PCNSL vs. others and 0.947 for HGG vs. metastasis. The ADC was only helpful in the tumor core and distinguishing PCNSLs from others (AUC = 0.897). Different from CBV-optimized protocols (preload, intermediate FA), PSR derived from the PSR-optimized protocol seems to be the most important parameter in the differentiation of HGGs, metastases, and PCNSLs at initial diagnosis. This property makes PSR remarkable and carries the need for comprehensive DSC-MRI protocols, which provides PSR sensitivity and CBV accuracy together, such as the preload use of the PSR-optimized protocol before the CBV-optimized protocol.[25]

6.3 AIMS AND OBJECTIVES OF THE STUDY

1. To evaluate the role of Perfusion parameter and Percentage Signal Recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.
2. To correlate with histopathological diagnosis wherever possible.

7.0 MATERIALS AND METHODS:

7.1 SOURCE OF DATA

A prospective study will be conducted over a period of one and half year from 15th Sep 2022 to 15th March 2024 on patients who will be referred to our institution Dayanand Medical College and Hospital for MR Brain in the Department of Radio-diagnosis, with clinical suspicion of brain tumor.

7.2 METHOD OF COLLECTION OF DATA

This prospective study will be done on patients who will be referred to the Department of Radiodiagnosis, Dayanand medical college and hospital for MRI Brain, with clinical suspicion of brain tumor during a period of one and a half year starting from 15th Sep 2022 to 15th March 2024. Only enhancing intra- axial brain lesions will be included in the study.

Inclusion Criteria

1.Imaging evidence of enhancing intra-axial brain tumor

Exclusion Criterion

1. Patients on chemotherapy/ radiotherapy.
2. Post operative cases.
3. Patients with alternative diagnosis
4. Patients who refuse to participate in the study

MR imaging technique

MR imaging will be performed on 3 T MR scan machine (Magnetom Skyra, Siemens, Germany) with a quadrature matrix head coil. Conventional sequences which will be included are: DWI (Resolve) axial, T2 TSE dark fluid transverse,SWI transverse, T2 TSE transverse, T1 TSE dark fluid, T2 TSE coronal, T2 TSE sagittal, followed by contrast administration andpost contrast sequences:T2 weighted echo planar imaging sequence (Ep2d_perf), T1 SE transverse fat sat post contrast, T1 MP-RAGE transverse post contrast 3d. After post contrast sequences spectroscopy csi-se 135 will be performed.

The paramagnetic gadolinium based contrast material will be administrated intravenouslythrough 18 or 20 gauge needle manually with the dose of 0.2 mmol/kg followed by 10 ml bolus of saline.All

perfusion data will be transferred to a stand-alone workstation for post processing on diagnostic color display system using dedicated advanced software package.

From processed perfusion images color-coded CBV and CBF maps will be obtained. For maximum CBV and CBF value for each tumor, multiple regions of interest of 25-40 mm2 will be manually drawn on enhancing solid portion of the lesion. Maximum CBV and CBF will be chosen and will be normalized by drawing similar sized ROI (Region of interest) on contralateral normal white matter. rCBV and rCBF values will be obtained by dividing maximum lesion CBV and CBF by normalized CBV and CBF. [rCBV and rCBF= maximum lesion CBV and CBF | normalized CBV and CBF]

In order to obtain signal intensity curve, ROI of 25-40 mm2 will be manually drawn on the post contrast T1W images at enhancing solid portion of tumor, carefully excluding the areas of necrosis or hemorrhage. Highest recovered signal intensity curve will be selected to calculate Percentage signal recovery (PSR). The percentage signal recovery (PSR) will be calculated using formula:

Percentage signal recovery (PSR) = 100% * [S1 – Smin] | [S0 – Smin]

Where S1 is post contrast T2 weighted signal intensity, S0 is pre-contrast T2 weighted signal intensity, and Smin is minimum T2 weighted signal intensity.

For normalization similar sized free hand ROI will be drawn on contralateral normal white matter and rPSR [rPSR = highest lesion PSR | normalized PSR] will be calculated.

Sequence	DWI (Resolve) axial	T2 TSE Dark fluid Transverse	SWI Transverse	T2 TSE Transverse	T1 TSE Dark Fluid	T2 TSE Coronal	T2 TSE Sagittal	Ep2d_ Perf	T1 SE Transverse Fat Sat	T1 MP-RAGE Transverse 3D
Acquisition time	2.03min	2.08 min	1.28 min	1.28 min	1.42 min	1.51 min	1.42 min	1.42 min	2.48 min	5.38 Min
Orientation	Transverse	Transverse	Transverse	Transverse	Transverse	Coronal	Sagittal	Transverse	Transverse	Transverse
Resolution Matrix	160* 100	320* 81	256* 80	512* 60	320* 91	512* 65	384* 75	128* 100	256* 70	256* 100
No. of slices	27	27	40/slab	28	28	25	25	20	25	176/ slab
FoV Read (mm)	220	220	220	220	220	220	230	220	220	230
FoV Phase (%)	100	87.5	90.6	87.5	87.5	87.5	100	100	84.4	100
Slice Thickness (mm)	4	4	3.5	4	4	4	4	4	4	1
Slice Gap (mm)	1.2	1.2	-	1.2	1.2	1.5	1.5	1.2	1.2	-
Repetition Time (msec)	5500	9000	27	5060	2000	5200	5270	1600	533	2200
TE (msec)	64	81	20	91	9	96	92	30	17	2.48
Flip Angle	180	130	15	120	150	150	140	90	58	8
Flow Compression	-	No	yes	Read	No	Read	Read	-	yes	No

STATISTICAL ANALYSIS

Data will be described in terms of range; mean +/- standard deviation (+/- SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Receiver operator characteristics (ROC) curve will be done, and criterion value will be estimated depending on the specificity and sensitivity. A probability value (p value) less than 0.05 will be considered statistically significant. All statistical calculation will be done using (Statistical Package for the Social Science) SPSS 21 version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft windows

OUTCOME:

Performance of perfusion parameters and percentage signal recovery derived from MR Dynamic Susceptibility Contrast Imaging in enhancing intra-axial brain tumors.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

The study will be performed on Siemens 3T MRI scan machine on patients with clinical suspicion of enhancing intra- axial brain tumors.

However, the study does not require any intervention to be conducted on patients, other humans and animals.

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Yes, Attached herewith

8. LIST OF REFERENCES

1. Mangla R, Kolar B, Zhu T, Zhong J, Almast J, Ekholm S. Percentage signal recovery derived from MR dynamic susceptibility contrast imaging is useful to differentiate common enhancing malignant lesions of the rain. AJNR Am J Neuroradiol. 2011;32:1004-10.
2. Smitha KA, Gupta AK, Jayasree RS. Relative percentage signal intensity recovery of perfusion metrics—an efficient tool for differentiating grades of glioma. Br J Radiol. 2015;88:20140784.
3. Calli C, Kitis O, Yunten N, et al. Perfusion and diffusion MR imaging in enhancing malignant cerebral tumors. Eur J Radiol. 2006;58:394–403
4. Weber MA, Zoubaa S, Schlieter M, Jüttler E, Huttner HB, Geletneky K, et al. Diagnostic performance of spectroscopic and perfusion MRI for distinction of brain tumors. Neurology. 2006;66:1899-906.
5. Le Bihan D, Douek P, Argyropoulou M, Turner R, Patronas N, Fulham M. Diffusion and perfusion magnetic resonance imaging in brain tumors. Top Magn Reson Imaging. 1993;5:25-31.
6. Chakravorty A, Steel TR, Chaganti JR. Accuracy of percentage of signal intensity recovery and relative cerebral blood volume derived from dynamic susceptibility-weighted, contrast-enhanced MRI in the preoperative diagnosis of cerebral tumours. Neuroradiol J. 2015;28:574-83.
7. Barajas RF, Cha S. Benefits of dynamic susceptibility-weighted contrast-enhanced perfusion MRI for glioma diagnosis and therapy. CNS Oncol. 2014;3:407-19.
8. Aronen HJ, Gazit IE, Louis DN, Buchbinder BR, Pardo FS, Weisskoff RM, et al. Cerebral blood volume maps of gliomas: comparison with tumor grade and histologic findings. Radiology. 1994;191:41-51.
9. Sugahara T, Korogi Y, Shigematsu Y, Hirai T, Ikushima I, Liang L, et al. Perfusion-sensitive MRI of cerebral lymphomas: a preliminary report. J Comput Assist Tomogr. 1999;23:232-7.

10. Cha S, Lupo JM, Chen MH, Lamborn KR, McDermott MW, Berger MS, et al. Differentiation of glioblastoma multiforme and single brain metastasis by peak height and percentage of signal intensity recovery derived from dynamic susceptibility-weighted contrast-enhanced perfusion MR imaging. AJNR Am J Neuroradiol. 2007;28:1078-84.
11. Hartmann M, Heiland S, Harting I, Tronnier VM, Sommer C, Ludwig R, et al. Distinguishing of primary cerebral lymphoma from high-grade glioma with perfusion-weighted magnetic resonance imaging. Neurosci Lett. 2003;338:119-22.
12. Liao W, Liu Y, Wang X, Jiang X, Tang B, Fang J, et al. Differentiation of primary central nervous system lymphoma and high-grade glioma with dynamic susceptibility contrast-enhanced perfusion magnetic resonance imaging. Acta Radiol. 2009;50:217-25.
13. Surendra K L, Patwari S, Agrawal S, Chadaga H, Nagadi A. Percentage signal intensity recovery: A step ahead of rCBV in DSC MR perfusion imaging for the differentiation of common neoplasms of brain. Indian J Cancer. 2020;57:36-43
14. Haldorsen IS, Espeland A, Larsen JL, et al. Diagnostic delay in primary central nervous system lymphoma. Acta Oncol 2005;44:728 –34
15. Roman-Goldstein SM, Goldman DL, Howieson J, et al. MR of primary CNSlymphoma in immunologically normal patients. AJNR Am J Neuroradiol. 1992;13:1207–13
16. KukerW, Nagele T, Korfel A. Primary central nervous system lymphomas (PCNSL): MRI features at presentation in 100 patients. J Neurooncol. 2005;72:169 –77
17. Jung BY, Lee EJ, Bae JM, Choi YJ, Lee EK, Kim DB. Differentiation between Glioblastoma and Solitary Metastasis: Morphologic Assessment by Conventional Brain MR Imaging and Diffusion-Weighted Imaging.Investig.Magn.Reson.Imaging. 2021;25:23-34

18. Schiff D. Single brain metastasis. Curr Treat Options Neurol 2001;3:89–99
19. Omuro A, DeAngelis LM. Glioblastoma and other malignant gliomas:a clinical review. JAMA.2013;310:1842-50
20. Sperduto PW, Chao ST, Sneed PK, Luo X, Suh J, Roberge D, et al.Diagnosis-specific prognostic factors,indexes, and treatment outcomes for patients with newly diagnosed brain metastases;a multi-institutional analysis of 4,259 pateints.Int J Radiat Oncol Biol Phys. 2010;77:655-61.
21. Pasricha S, Gupta A, Gawande J, Trivedi P, Patel D. Primary central nervous system lymphoma:a study of clinicopathological features and trend in western India. Indian J Cancer.2011;48:199-203
22. Cha S. Update on brain tumor imaging; from anatomy to physiology. Am J Neuroradiol. 2006;27:475-487.
23. Louis DN, Ohgaki H, Wiestler OD. The 2007 WHO classification of tumours of the central nervous system. Acta Neuropathol. 2007;114:97-109
24. Faehndrich J, Weidauer S, Pilatus U, Oszvald A, Zanella FE, Hattingen E. Neuroradiological viewpoint on the diagnostics of space-occupying brain lesions. Clin Neuroradiol. 2011;21:123-39
25. Cindil E, Sendur HN, Cerit MN, Dag N, Erdogan N, Celebi FE, et al. Validation of combined use of DWI and percentage signal recovery-optimized protocol of DSC-MRI in differentiation of high-grade glioma, metastasis, and lymphoma. Neuroradiology. 2021;63:331-42.
26. Lee MD, Baird GL, Bell LC, Quarles CC, Boxerman JL. Utility of Percentage Signal Recovery and Baseline Signal in DSC-MRI Optimized for Relative CBV Measurement for Differentiating Glioblastoma, Lymphoma, Metastasis, and Meningioma. AJNR Am J Neuroradiol. 2019;40:1445-50.

PROFORMA

S. No.	Name-	Age-
Gender	Case No.	MRD No.
Address	Contact No.	Referring doctor

Past history

Family history of brain tumor\ any other tumor

Chief presenting complaints:

-Headache

-Nausea/vomiting

-Vertigo

-Paralysis/ paresis

-Seizure

-Any other

Laboratory investigations

- Hemogram

    Hb

    TLC

    Platelets

-RFTs

    Creatinine

Provisional Diagnosis

Previous imaging

MRI findings:

Signature of Candidate **Signature of Supervisor**

Sequences	Signal appearance
T1W	
T2W/FLAIR	
Diffusion restriction (Present/Absent)	
Contrast enhancement pattern	
Spectroscopy	

No. of enhancing lesions:

Perfusion Parameters:

Normalised rCBF					
Normalised rCBV					
PSR					
Normalised rPSR					

Radiological Imaging Diagnosis

Histopathology Diagnosis

Correlation with histopathology

-Concordance

-Discordance

Signature of Candidate **Signature of Supervisor**

INFORMED PATIENT CONSENT

Date: _____

I……..D/o, W/o, S/o……. am willing to participate in the study "**ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS**" The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

……. ……

Signature of the Witness Signature of the patient

Name:

Signature of Candidate Signature of Supervisor

फार्म

तिथि_____

मैं_____ नीपत्/पुत्र/ पुत्री_____ निवासी _____ शोधकार्य इस "**ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS**" में मैं हूँ। तैयार से स्वेच्छा अपनी लिए के लेने भाग में शोधकार्य इस मैं हूँ। सहमत लिए के लेने भाग करता टिपुष्/ और गया दिया नहीं प्रलोभन आर्थिक कोई मुझे लिए के देने स्वीकृति यह की हूँ करती यह मुझे और है गया दिया कर टस्पष् देश्यउद् का शोधकार्य इस मुझे है। गया डाला दबाव ही न वाले होने में शोधकार्य इस मुझे है। लिए के लाभ के मानवता और विज्ञान यह की है वासविश् है। मामुली बहुत जोखिम यह में समझ मेरी और है गया दिया समझा में बारे के जोखिम

कर तव्यक् अस्वीकृति अपनी समय भी किसी में सम्बन्ध के लेने भाग में शोधकार्य इस मैं सकता/पड़ेगा। नहीं प्रभाव कोई पर इलाज मेरे का करने तव्यक् अस्वीकृति मेरे और हूँ सकती

_____ _____

हस्ताक्षर के गवाह
नाम:

हस्ताक्षर के रोगी/ निशान का अंगूठे
नाम:

_____
अन्वेषक के हस्ताक्षर

_____
हस्ताक्षर के विद्यार्थी

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

"**ROLE OF PERFUSION PARAMETERS AND PERCENTAGE SIGNAL RECOVERY DERIVED FROM MR DYNAMIC SUSCEPTIBILITY CONTRAST IMAGING IN ENHANCING INTRA-AXIAL BRAIN TUMORS**" ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ